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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

VOL. XIII. 1918. Nos. 1 to 12.

A MONTHLY JOURNAL FOR ENGINEERS, ARCHITECTS, SURVEYORS & CONTRACTORS and all interested in CEMENT, CONCRETE, REINFORCED CONCRETE, FIRE-RESISTING CONSTRUCTION and STRUCTURAL STEEL.

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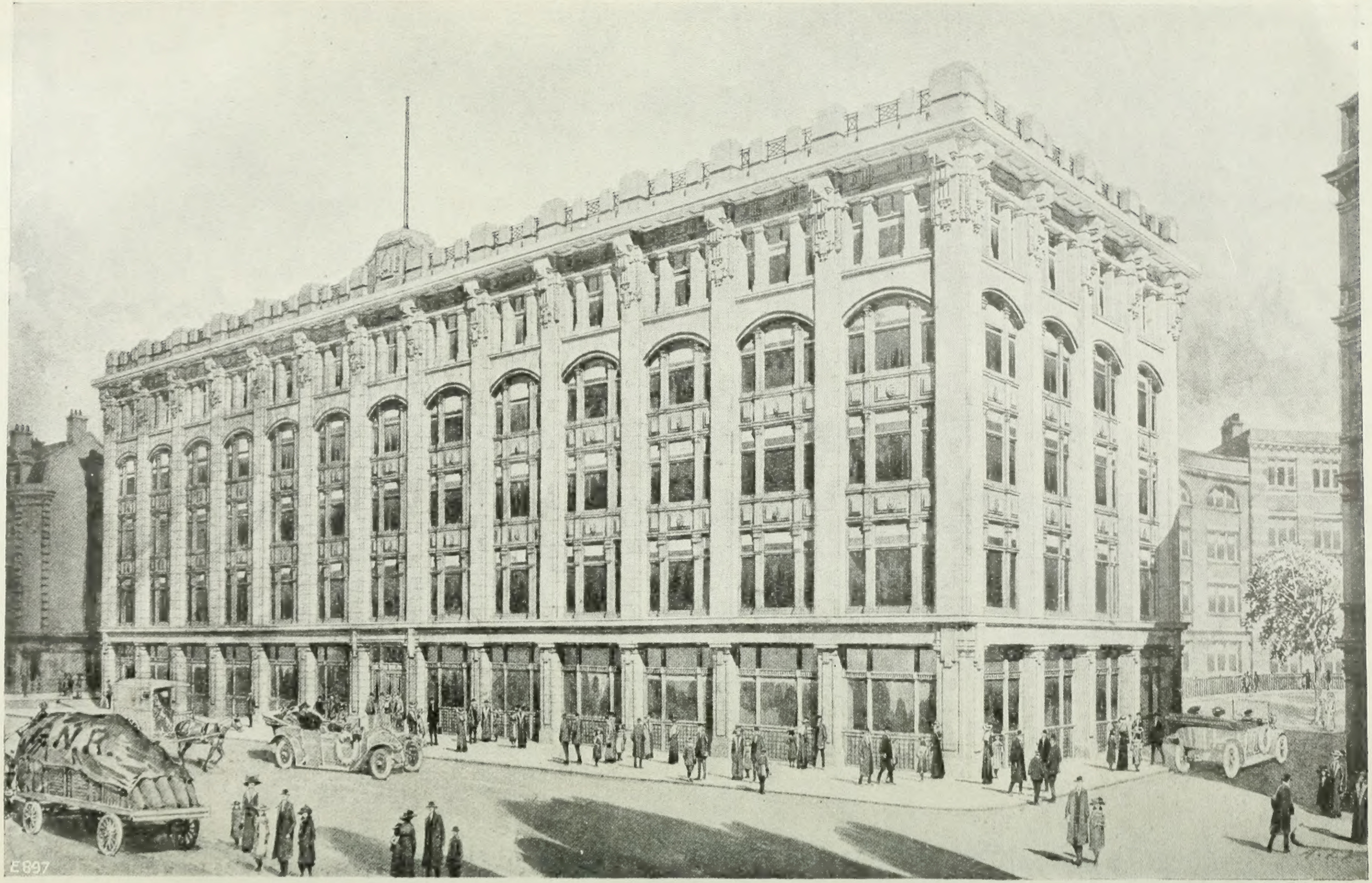


General Elevation.

A Factory, Tottenham Court Road.

(*For Description see page 3.*)

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XIII., No. 1. LONDON, JANUARY, 1918.

EDITORIAL NOTES.

CONCRETE IN 1917.

THE past year has seen a remarkable development in the public interest accorded to concrete. In pre-war days great works of concrete and reinforced concrete were completed—docks, warehouses, viaducts, bridges, etc.—but, somehow, these remarkable developments in the application of concrete and reinforced concrete never struck the public fancy, and, as a matter of fact, even the public authorities, who should have given the subject considerable attention, were apathetic in their conservatism. To-day, however, the mere fact that the enemy has been using concrete on a large scale on the Western Front in the construction of dug-outs, pill-boxes, and similar works, and the constant reference to these structures in the daily Press, has led the public to understand the nature and adaptability of concrete as a building material. As to its adaptability, it is now nearly ten years ago when we published in these columns the first examples of barges, ships, and floating docks constructed of reinforced concrete, but again those primarily concerned scarcely evinced any interest in the subject, and the public did not realise what this meant.

Further, to-day, when the absolute necessity of additional tonnage is understood by the public, and the difficulty of obtaining steel for shipbuilding is realised, and the daily Press is constantly giving space to the question of ships and boats constructed of concrete and reinforced concrete, the " man in the street " has become aware of the many different ways in which the material can be applied.

Between the rough-and-ready concrete work of the enemy on the Western Front and its skilful application in shipbuilding work there is, however, a vast field for the use of this form of construction. Now that bricks are scarce, and timber is costly and also difficult to obtain, it is being gradually understood that concrete may become an economical and useful building material for domestic buildings as well as for the erection of factories, municipal buildings, for road work, bridges, etc.

The scarcity of timber has made the public realise the advantages of concrete as a substitute for a variety of minor purposes; the concrete fencepost is coming into its own, and the material is finding increasing favour for the many accessories needed on the farm and the estate.

Nineteen hundred and seventeen will accordingly be a landmark in the history of modern concrete and reinforced concrete construction, for the great public has become alive to the advantages of the material, and we actually find

Government departments and public authorities recommending its use as a substitute for timber and steel.

The necessity of economy engendered by the war has probably done more than anything else to teach authorities, professional men, and the public what the Romans understood years ago, that concrete is a practical and economic factor in building construction. We must also remember that the United States, our Allies in France and Italy, and our enemies have been using it on an extraordinarily extensive scale for close on two decades.

The coming year should see a further appreciation of the utility of concrete and everything that can be done to make its advantages understood by those concerned should be undertaken.

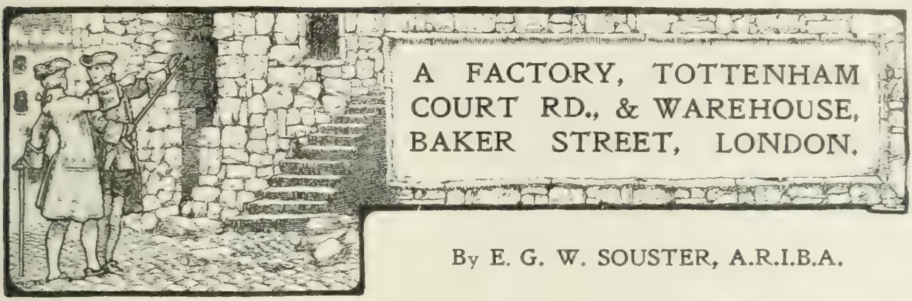
Concrete spells progress in simple structural work, but it also spells economy and adaptability. We need hardly say that we trust this JOURNAL will contribute to a better understanding of the use of this material throughout the Empire.

AIR RAIDS AND CONCRETE.

WHEN so much is being said about housing schemes and the development of industrial structures, attention should be called specially to the necessity of according greater attention in the future, than heretofore, to the question of protection from air-raid dangers as far as roof and floor construction is concerned. This applies not only to the public building or the building of an industrial character, but equally of structures of a domestic character, especially in the larger private residences and in blocks of flats and tenements. Even if such buildings cannot readily be made bomb-proof, they should at least be made sufficiently proof against minor projectiles, such as shells and shrapnel, and this is certainly not the case where ordinary tile or slate roofs are met with or where timber flooring is used.

The solution to the question probably lies in a considerable application of concrete in all classes of buildings; whether solid, reinforced, or hollow remains to be seen.

New methods of roof construction will have to be found and adopted, and new forms of light floor construction will probably have to be devised; but, generally speaking, our contention is that among the many factors arising in connection with the new building problems not least is that of affording reasonable security against air attack.



A FACTORY, TOTTENHAM COURT RD., & WAREHOUSE, BAKER STREET, LONDON.

By E. G. W. SOUSTER, A.R.I.B.A.

The following are two examples of interesting steel frame and concrete buildings.—ED.

THE statement is sometimes made that the design of factory and industrial buildings and the simplicity of their lines do not allow for the possibility of architectural character to be given to them.

This statement seems to spring from a mistaken notion that architectural character is something that can be given to a building—firstly, by sacrificing certain uses for the purpose of gaining effects, and, secondly, by adding extraneous ornament; and both opinions are erroneous. Rightly understood, architectural character in any building is the expression of its construction, and in a modern steel-framed or reinforced concrete building, where the weights of each part are carried direct to stancheons or piers placed at regular intervals, the designer may by the exercise of thought and at little cost give an impression of power and dignity that can only otherwise be obtained in large public buildings.

The monotonous appearance of the factory of a generation ago is apparent to everyone, and it must also be granted that when money was allowed for the elevations, ornament and details that would have been just as much in place on a block of flats or even on a town hall were often wrongly employed.

To-day the manufacturer is beginning to realise that a well designed elevation is useful to him from an advertisement point of view, and the tendency of architects to concentrate on the structural lines of the building is exemplified in the two buildings here described and illustrated.

FACTORY, TOTTENHAM COURT ROAD.

This building occupies a site at the corner of Tottenham Court Road and Chenies Street, whilst part of the rear elevation abuts on an open space.

At present only a portion of the structure is finished, but the drawing (see Frontispiece) and the bays already erected prove that the conditions necessary for successful lighting have been solved without interfering with the uses of the structure.

The building is planned to contain both the offices and workshops of the company and possesses several interesting features.

The fresh air to the upper floor is admitted through gratings or pierced cast-iron bosses in the panels under windows, to a duct which runs from pier to pier (see *Fig.* 3). Under each window a radiator or coil of pipes is placed, and the heat, passing through a thin slab, warms the air, whilst provision is also made for fixing hot water pipes in the duct should greater temperatures be required.

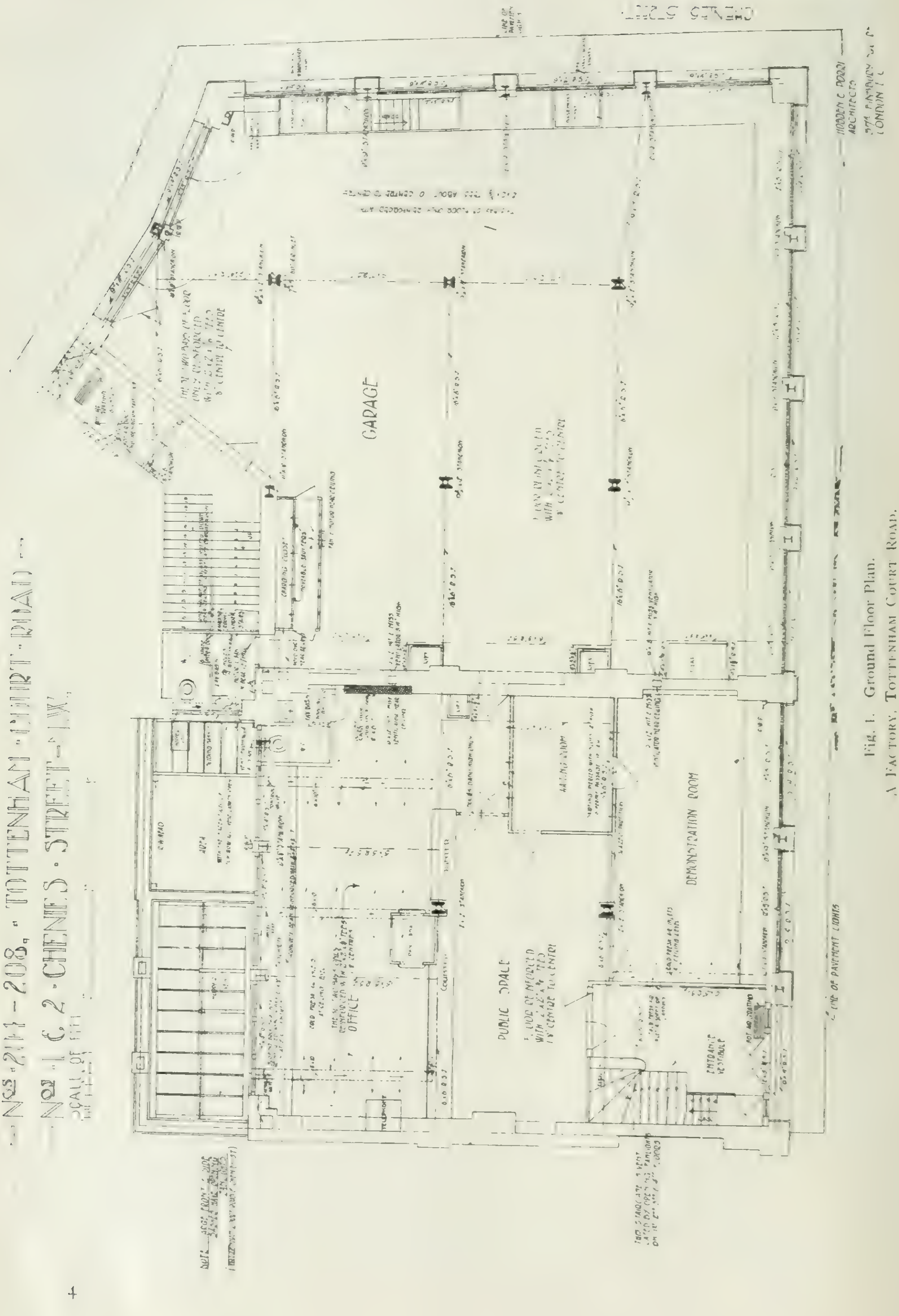


Fig. 1. Ground Floor Plan.
A Factory, Tottenham Court Road.

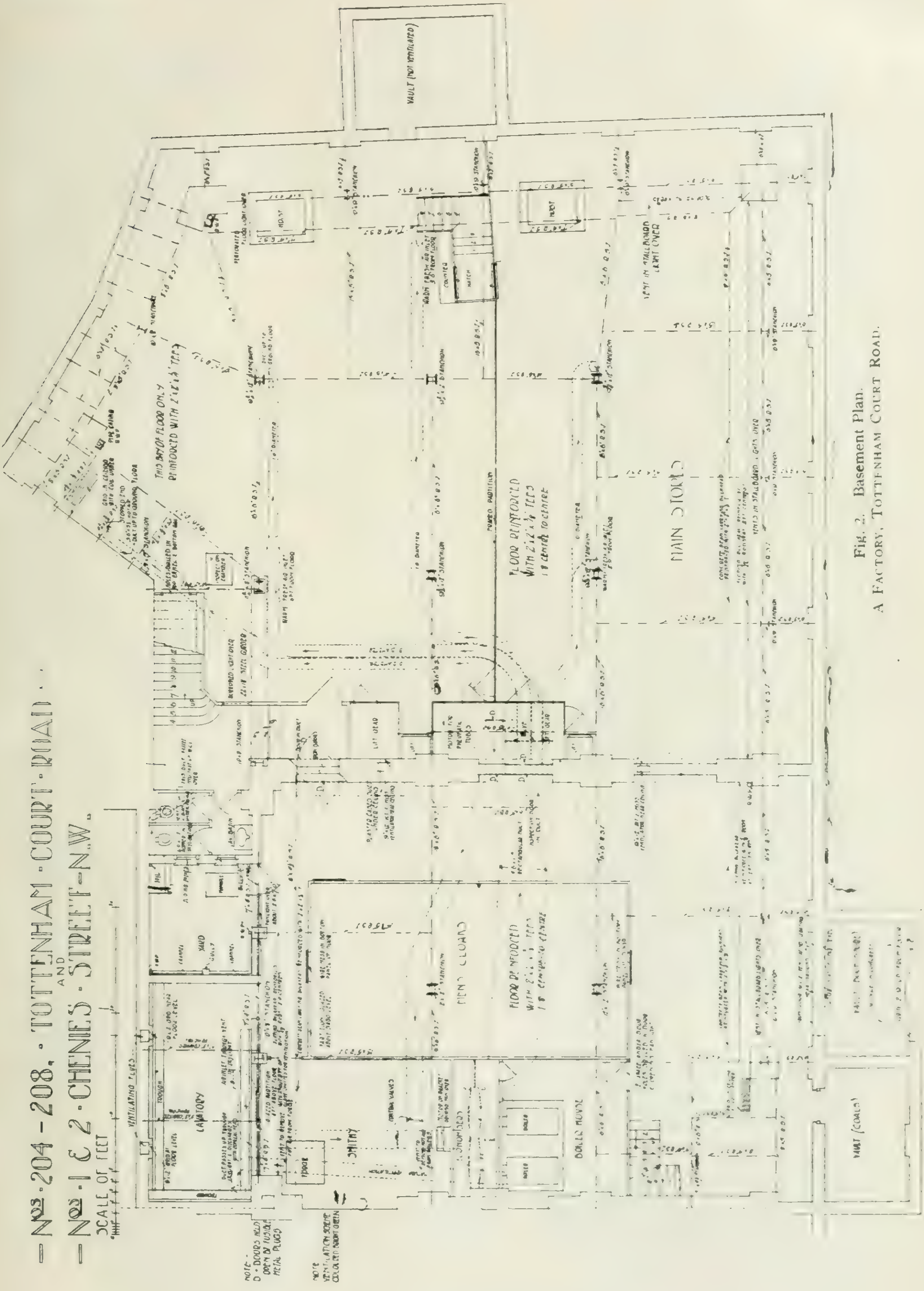

Nos. 204 - 208 · Tottenham · Court · Road
and
Nos. 1 & 2 · Chenies · Street-N.W.
Scale of feet
Vault (not ventilated)
Main Stores
Men's Cloaks
Floor reinforced with 2½ x 2½ x ¼ Tees 1' 0" centre to centre
This bay of floor only reinforced with 2½ x 2½ x ¼ Tees
Lift Head
Smithy
Boiler House
Lavatory
Yard
Ventilating flues
Vault (Coals)
Note - D - Doors held open by fusible metal plugs
Note Ventilation scheme coloured bright green

Fig. 2. Basement Plan.
A Factory, Tottenham Court Road.

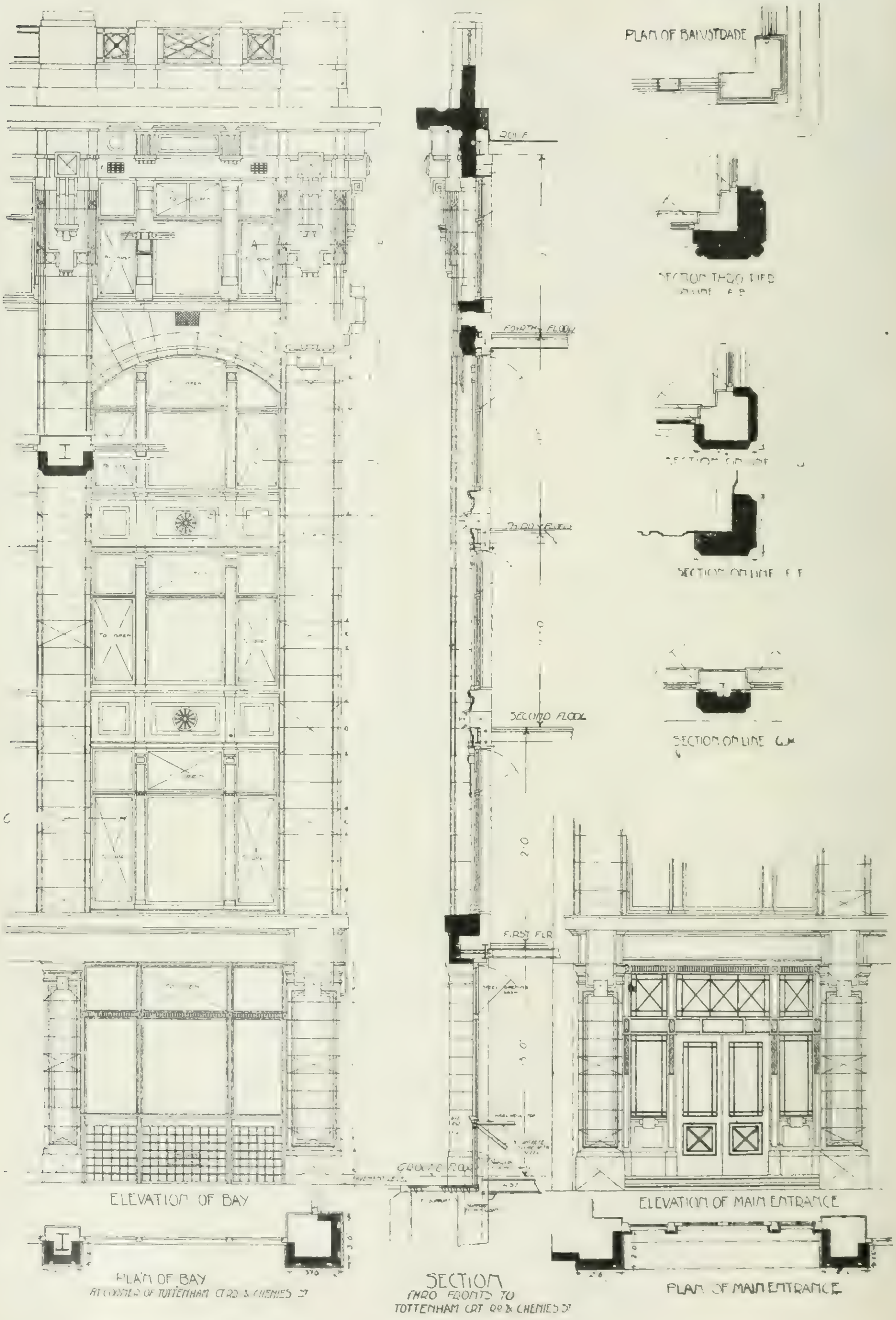


Fig. 3. Details.
A Factory, Tottenham Court Road.

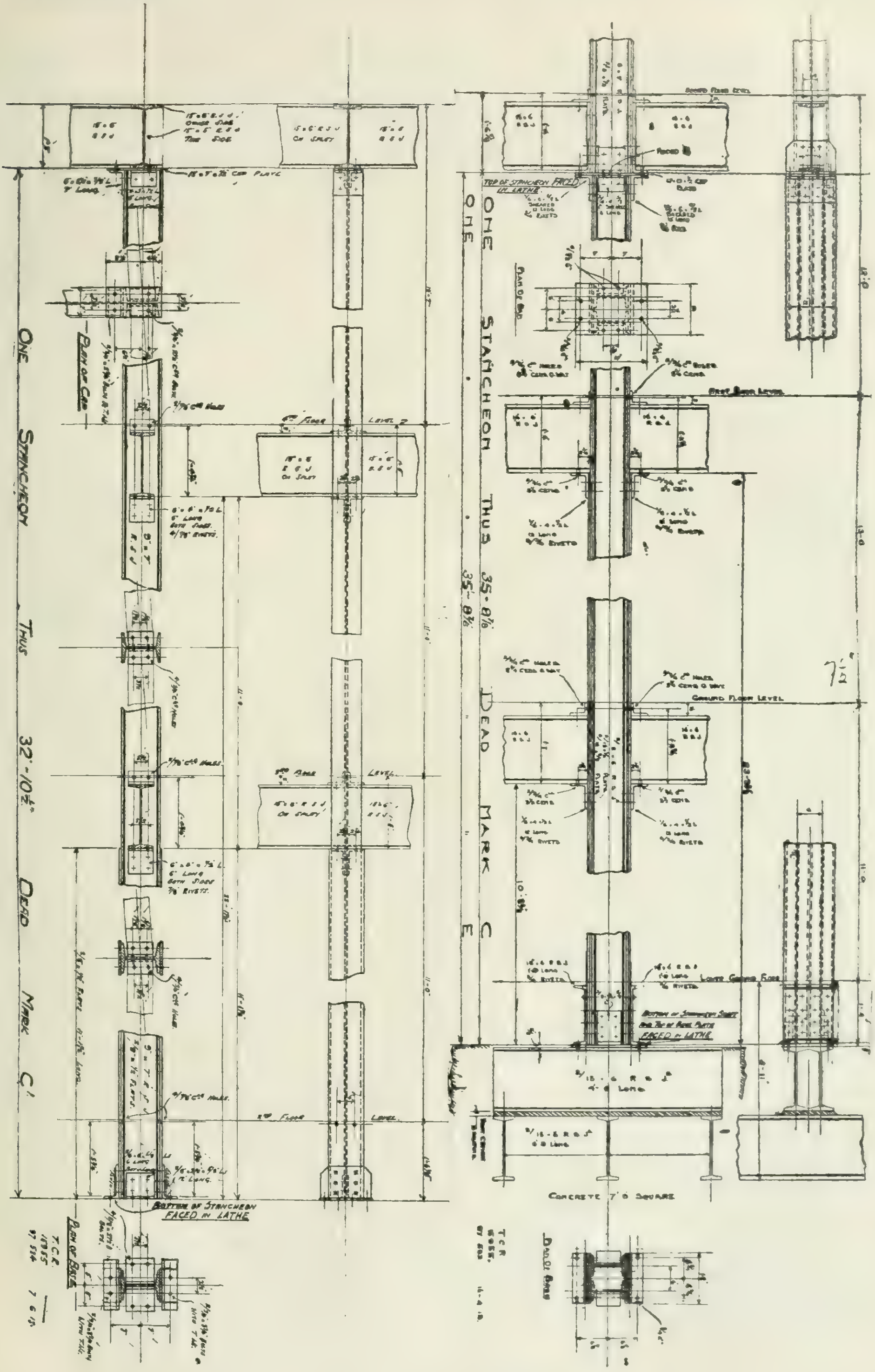

ONE STANCHEON THUS 32'-10½" DEAD MARK C'
PLAN OF CAP
PLAN OF BASE
BOTTOM OF STANCHEON FACED IN LATHE
ONE STANCHEON THUS 35'-8⅜" DEAD MARK E C
TOP OF STANCHEON FACED IN LATHE
PLAN OF CAP
FIRST FLOOR LEVEL
GROUND FLOOR LEVEL
GROUND FLOOR LEVEL
LOWER GROUND FLOOR
BOTTOM OF STANCHEON SHAFT AND TOP OF BASE PLATE FACED IN LATHE
CONCRETE 7'0 SQUARE
PLAN OF BASE
T.C.R.
1785
7 6 13
7½"

Fig. 4. Stancheon Details.
A Factory, Tottenham Court Road.

The inlets from these ducts to the rooms are at ceiling level and are controlled by a simple mechanism to allow greater or lesser amount of air to enter rooms.

Throughout the building air is admitted at the ceiling level and is withdrawn near the floor, and thus all particles of dust, etc., given off by the machines are carried downwards and removed. There is thus no possibility of workers inhaling air charged with foreign matters. Moreover, to prevent the annoyance of cold sheets of air falling on those working at benches near windows, a gilled hot water pipe is fixed below the bench under each window. This pipe is contained in a chamber divided in such a manner that the air, after being warmed, rises up to the bench and a layer of warmed air is constantly present between the cold window surface and the worker.

In order to eliminate the waste of furnace gases and heat from the boiler an economiser system is installed, and by it the whole of the basement atmosphere is warmed.

Ventilation and change of air to all rooms is effected by the provision of louvres in the lower panels of doors to staircase, on the roof of which a large fan chamber is formed.

The sanitary conveniences are ventilated by a shaft running along back and connected with all w.c. apparatus, which are of special form.

This duct is joined at each floor to an upcast duct leading to fan chamber on roof, and experience has proved that no possibility exists of fouled air entering the working portion of the premises.

Ample lighting is provided by the windows, but to give a maximum of daylight to the basement a bulkhead is formed on ground floor and continuous pavement lights constructed in footway; moreover, in order to obviate the necessity of a R.S.J. at the pavement level, the inner edge of pavement lights rests on an angle iron support fixed to suspension T's from a 6-in. by 5-in. R.S.J. fixed behind stallboard casing.

The building is of steel-framed construction with stancheons in all piers except those at ends of party walls and at corners of streets. A typical stancheon is shown in *Fig.* 4.

Within the building the stancheons are placed to divide the structure into fairly equal units, but to reduce the number of supports as far as possible they are not disposed to line with the spacing of piers to front elevation.

The ground, first, and second floors are of concrete, reinforced with 2-in. by 2-in. by $\frac{3}{8}$ T's, spaced at 20-in. centres, and with main beams of 18-in. by 7-in. and 16-in. by 6-in. R.S.J.'s, whilst remainder of floors and roof are of concrete, reinforced with monolithcrete joists, and on the latter three large north lights are formed. The elevation of the building is faced with Portland stone, the panels between windows being of cast-iron.

WAREHOUSE, BAKER STREET, W.

These buildings have been but lately completed, and, owing to the war, temporary enclosures have been used for the ground story openings. The building, as will be seen from the plans, consists of open floors, served by both staircases and lifts.

A WAREHOUSE, BAKER STREET.

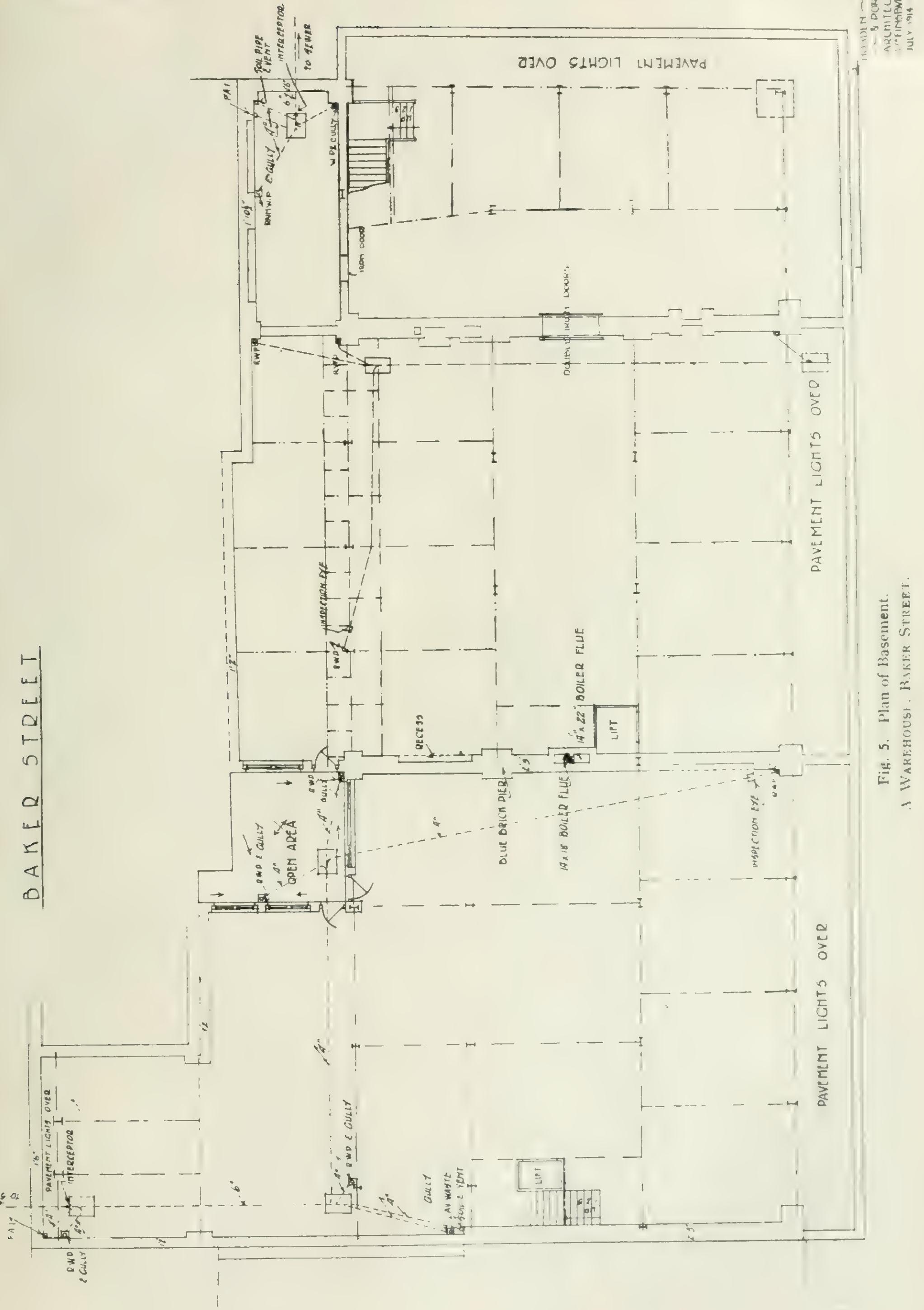


Fig. 5. Plan of Basement.
A Warehouse, Baker Street.

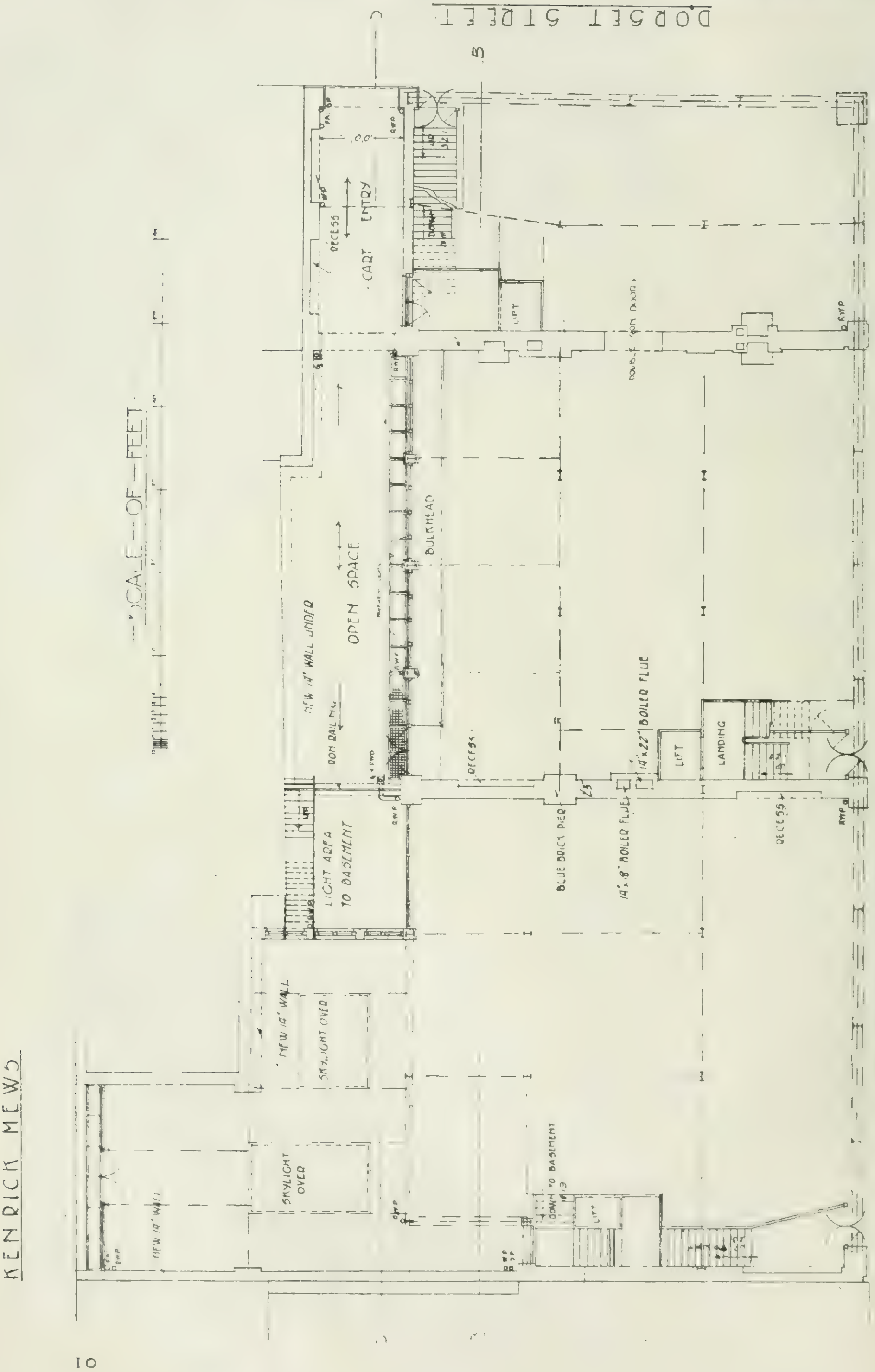


Fig. 6. Ground Floor Plan.
A Warehouse, 'Baker Street.

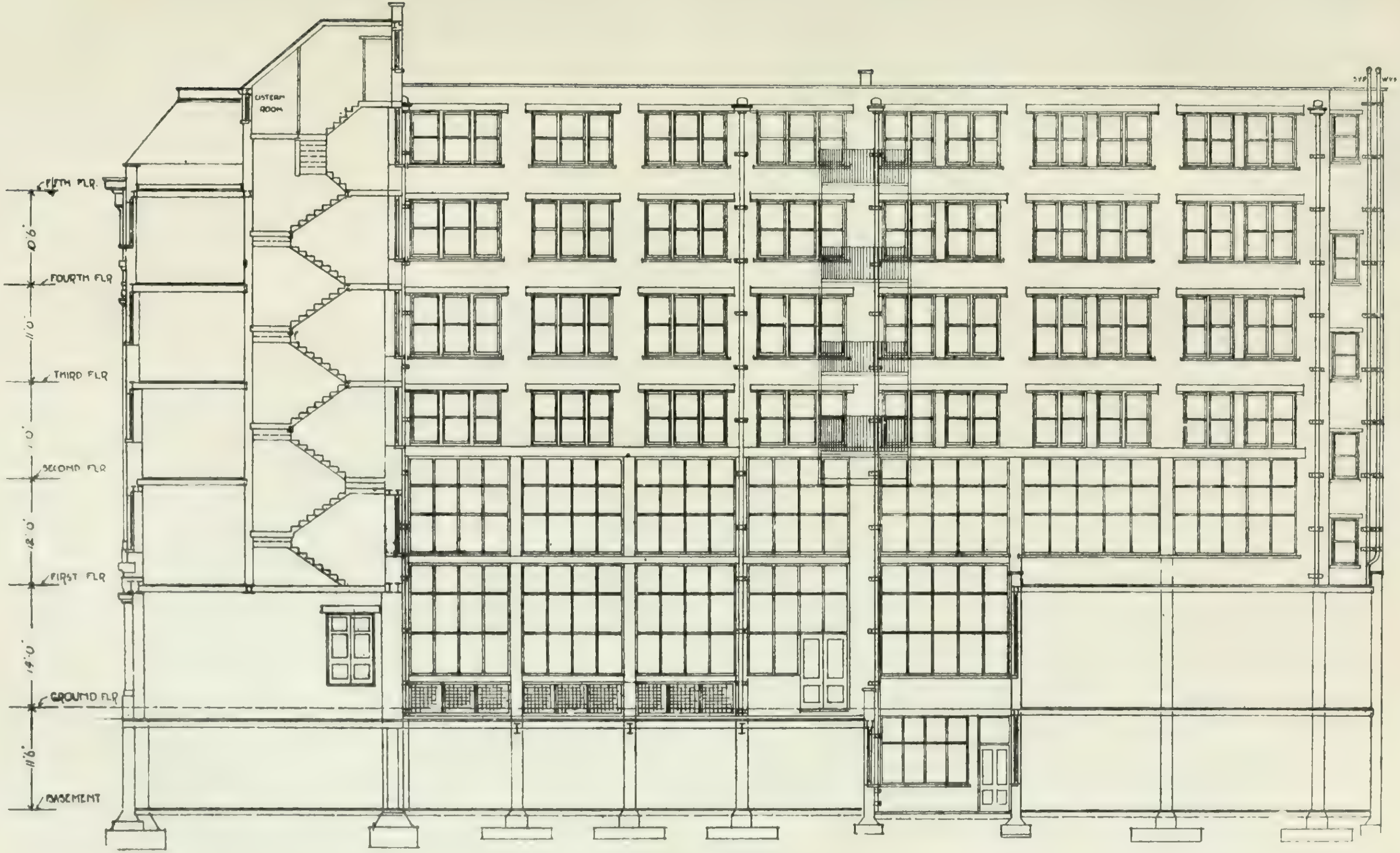


Fig. 7. Section.
A Warehouse, Baker Street.

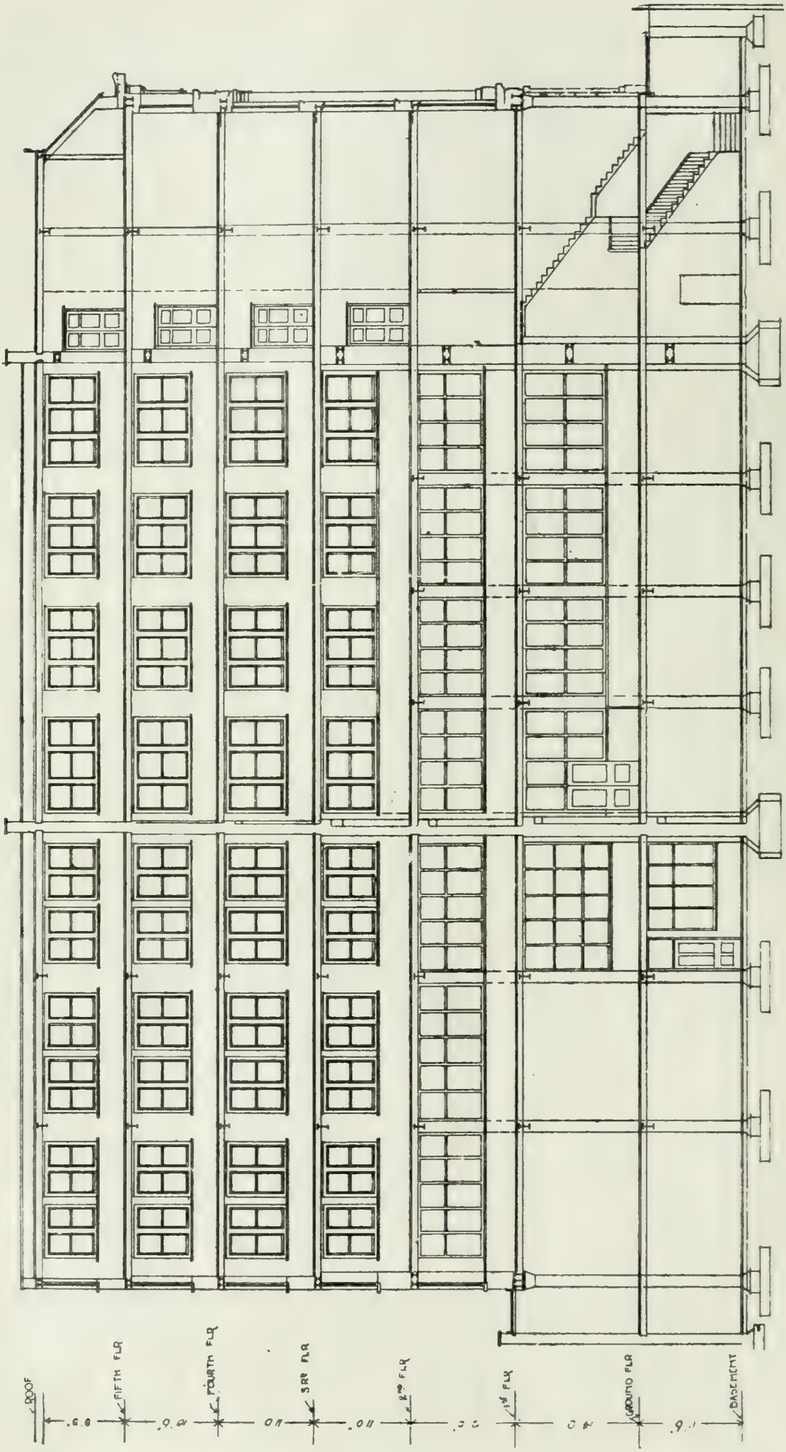


Fig. 8. Section.
A Warehouse, Baker Street.

Steel-framed and concrete construction, with facing of Portland stone for elevations to main streets, is used, and the building, whilst possessing abundant natural lighting surface, has a dignity and character that is too often lacking in this class of structure.

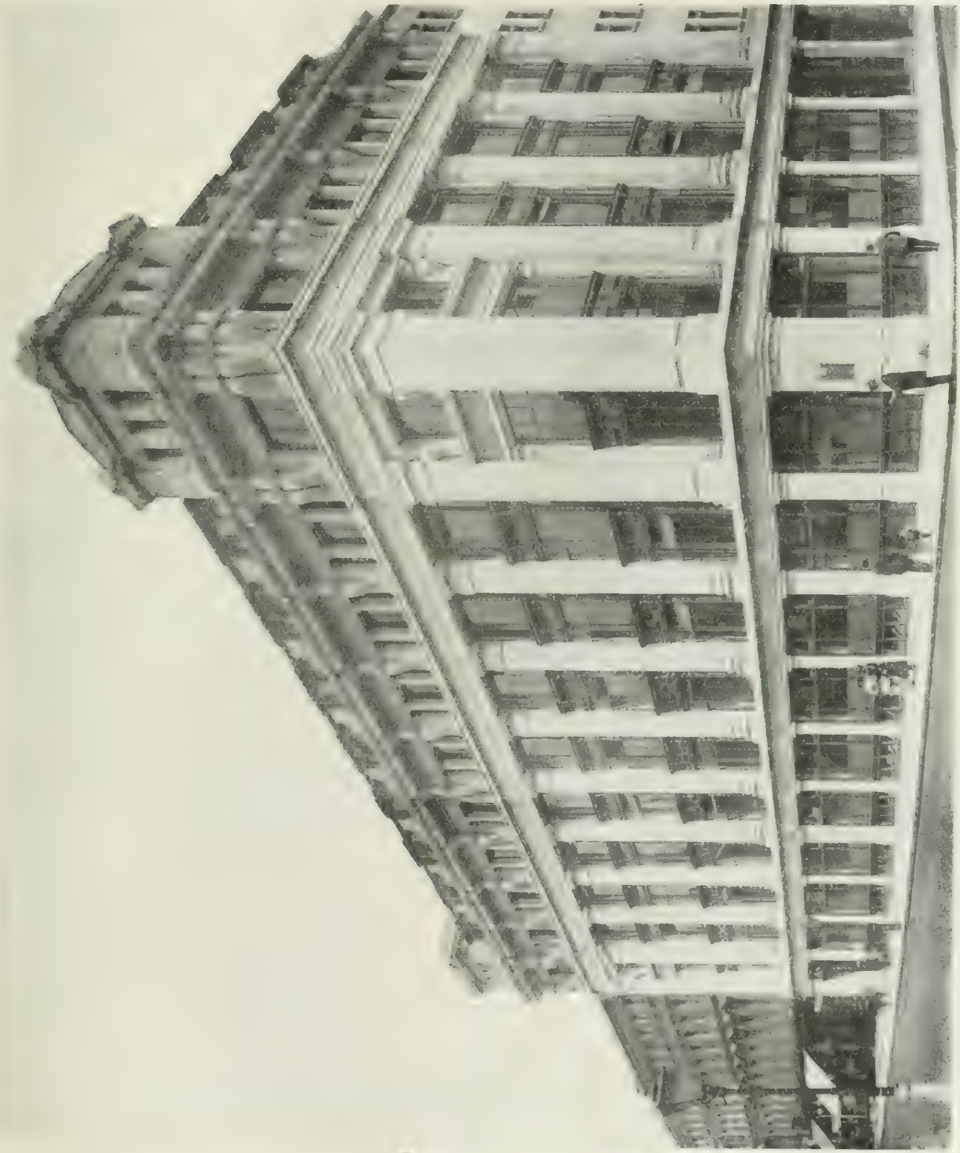
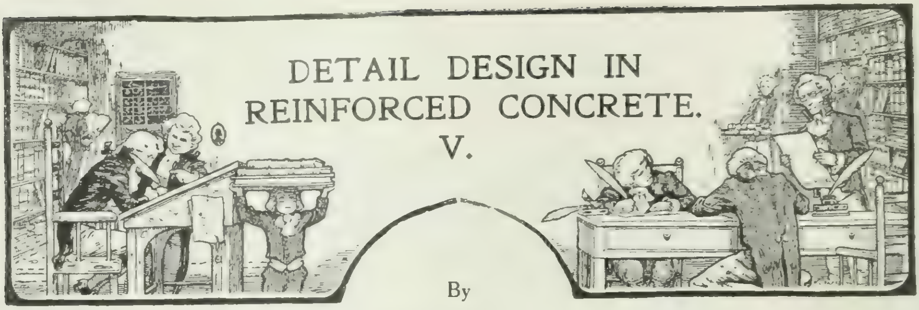


Fig. 9. General View.
A Warehouse, Baker Street.

The architects for both buildings were Messrs. Hobden and Porri, of 37A, Finsbury Square, E.C.; Messrs. Moreland and Sons carried out the steelwork for Tottenham Court Road, and Messrs. Drew, Bear, Perks that for Baker Street.

DETAIL DESIGN IN REINFORCED CONCRETE.

V.



By

EWART S. ANDREWS, B.Sc.Eng., M.C.I.

The last article of this series appeared in our issue of September, 1917.—ED.

DESIGN OF FOOTINGS FOR PILLARS.

THE L.C.C. regulations do not specify the method of calculation to be employed for footings, but call only for the following maximum pressures on the soil (regulation **136**).

	Tons per sq. ft.
Natural bed of soft clay or wet or loose sand	1
,, ,, ordinary clay or confined sand	2
,, ,, compact gravel, London blue clay or chalk	4

We will now proceed to explain the considerations involved in the design of an ordinary square or rectangular footing, and will illustrate them by the numerical example of the pillar which we dealt with in the last article.

This pillar is an internal one, and the building is of such a nature that it has not been considered necessary to provide for bending moments in the pillar, so that we may assume that the pressure of the footing upon the ground is uniformly distributed. If there were a bending moment on the pillar, we should have to deal with a varying load on the base in a similar manner to that employed in a retaining wall, which we propose to deal with in a subsequent article.

Size of Footing.—The load transmitted by the pillar has been shown to be 315 kips, and we will take the soil as being ordinary clay upon which the permissible pressure is 2 tons per sq. ft.—*i.e.*, 4·48 kips per sq. ft. Assuming that the weight of the footing itself is 10 per cent. of the load transmitted, we shall have a total pressure on the soil equal to $315+31=346$ kips.

$$\therefore \text{ area of footing required} = \frac{346}{4\cdot48} = 77\cdot2 \text{ ft.} - \text{say 9 ft. sq.}$$

The weight of the footing itself need be taken into account only in determining the area of the base, and need not be allowed for in determining the stresses in the base, since the downward weight is neutralised by the corresponding portion of the upward pressure.

The L.C.C. regulations do not give very definite rules for footings, but the minimum effective depth of the footing might be determined by regulation **66**, which states that for 1 : 2 : 4 concrete $\frac{S}{b_r d}$ shall not exceed three times the permissible shear stress on the concrete ; in our case this means that $\frac{S}{b_r d}$ shall not exceed 180 lb. per sq. in.—*i.e.*, 0·18 kips per sq. in.

The value of b_r to be taken is the perimeter of the column—*i.e.*, $4\times24=96$ in.

The value to be taken for S = Total load on column $\left\{\dfrac{\text{area of footing} - \text{area of column}}{\text{area of footing}}\right\}$

$$=315\left\{\frac{81-4}{81}\right\}=\frac{315\times 77}{81}=300 \text{ kips.}$$

$$\therefore \frac{S}{b_r d}=\frac{300}{96d}, \text{ and this must not exceed } 0{\cdot}18$$

$$\therefore \text{ minimum value of } d=\frac{300}{0{\cdot}18\times 96}=17{\cdot}4 \text{ in.}$$

Although this depth would apparently satisfy the regulation considered, it is less than desirable for several reasons. In the first place the stress in the column at the base is 0·633 kips per sq. in., so that the stress in the steel is $15\times 0{\cdot}633=9{\cdot}5$ kips per sq. in., and if we provide hooks at the end, we shall be allowed a grip stress by regulation **45** (*a*) of 100 lb. per sq. in. For a plain bar a diameter d of length l the grip load $=\pi dl\times 100$ lb. = at least load on bar $=\dfrac{9{\cdot}5\times\pi d^2}{4}\times 1{,}000$ lb.

$$\therefore l=\frac{95d}{4}=\frac{95\times 7}{32} \text{ for } \tfrac{7}{8}\ \phi \text{ bar used} = 20{\cdot}8 \text{ inches}$$

to develop a permissible grip stress, therefore, between the steel in the column and that in the footing we must have at least 20·8 in., and it is desirable for the grip length to be sufficient to develop nearly the full strength of steel—viz., 40 diameters or $l=35$ in.

We have also to remember that the footing acts as a beam, and that we shall save steel by increasing the depth. It should also be noted that the shear round the edge of the column is what is sometimes referred to as "punching shear," and that 120 lb. per sq. in. is commonly considered as high a value as this should have. We have adopted an effective depth of 34 in. on the assumption that there is no special need to make the depth as small as possible.

Bending Moments to be taken in design.—We have indicated already that the problem of the stresses in a footing comes under one of the special cases of slabs which cannot be analysed rigidly. The usual treatment based upon Professor Talbot's experiments* is as follows :

We regard the stresses as resisted by four cantilevers, each of which carries a load represented by the area *ABCD*, *Fig.* 18.

If w is the load per sq. ft. on the soil, we can divide the area up into a rectangle *DCEF* and two triangles *ADE*, *BCF*.

The moment about CD of the load on the rectangle $=wxb\times\dfrac{x}{2}$, and the moment contributed by the two triangles $=\dfrac{2wx^2}{2}\times\dfrac{2x}{3}=\dfrac{2wx^3}{3}$

$$\therefore \text{ Total bending moment about } CD=w\left(\frac{bx^2}{2}+\frac{2x^3}{3}\right)=B=wx^2\left(\frac{b}{2}+\frac{2x}{3}\right)$$

$$\therefore \text{ putting } x=\frac{(l-b)}{2} \text{ we have}$$

$$B=w\frac{(l-b)^2}{4}\left(\frac{b}{2}+\frac{l-b}{3}\right)$$

$$=\frac{w(l-b)^2}{24}\left(2l+b\right)$$

$$=\frac{wl^3}{24}\left(1-\frac{b}{l}\right)^2\left(2+\frac{b}{l}\right)$$

---

* University of Illinois Bulletin No. 67, "Reinforced Concrete Wall Footings and Column Footings," by Arthur N. Talbot. (London: Chapman and Hall, Ltd.)

but wl^2 = total load on column = W

$$\therefore B = \frac{Wl}{24}\left(1-\frac{b}{l}\right)^2\left(2+\frac{b}{l}\right)$$
$$= Q_1 . Wl$$

where Q_1 is a coefficient dependent upon $\frac{b}{l}$, and values of which are given in the diagram of *Fig.* 19.

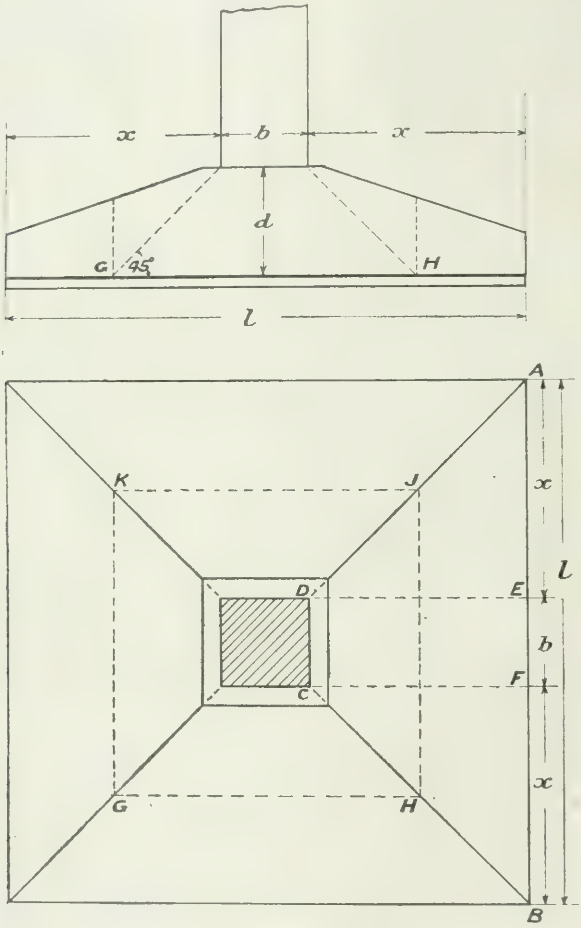


Fig. 18.

Effective Breadth of Cantilever.—The effective breadth b_e of the cantilever, which is to be regarded as carrying this bending moment, is proposed by Professor Talbot as the result of his experiments as equal to

$$b_e = b + 2d + \tfrac{1}{2}(l - b - 2d)$$

where d is the effective depth of the footing, which in our case we will take as 34 in.

$$\therefore b_e = 24 + 68 + \tfrac{1}{2}(108 - 24 - 68) = 100 \text{ in.}$$

This is practically the full breadth of the footing, and it comes to this high value because we have adopted a deep footing; in any case in which the value of b_e, calcuated by Talbot's formula, exceeds the length of the footing, we should, of course, take $l_e = l$.

Reinforcement Required.—The load W to be provided for in our case is 315 kips, and we have $l = 108$ in. and $b = 24$ in.

$$\therefore \frac{b}{l} = \frac{24}{108} = 0 \cdot 222$$

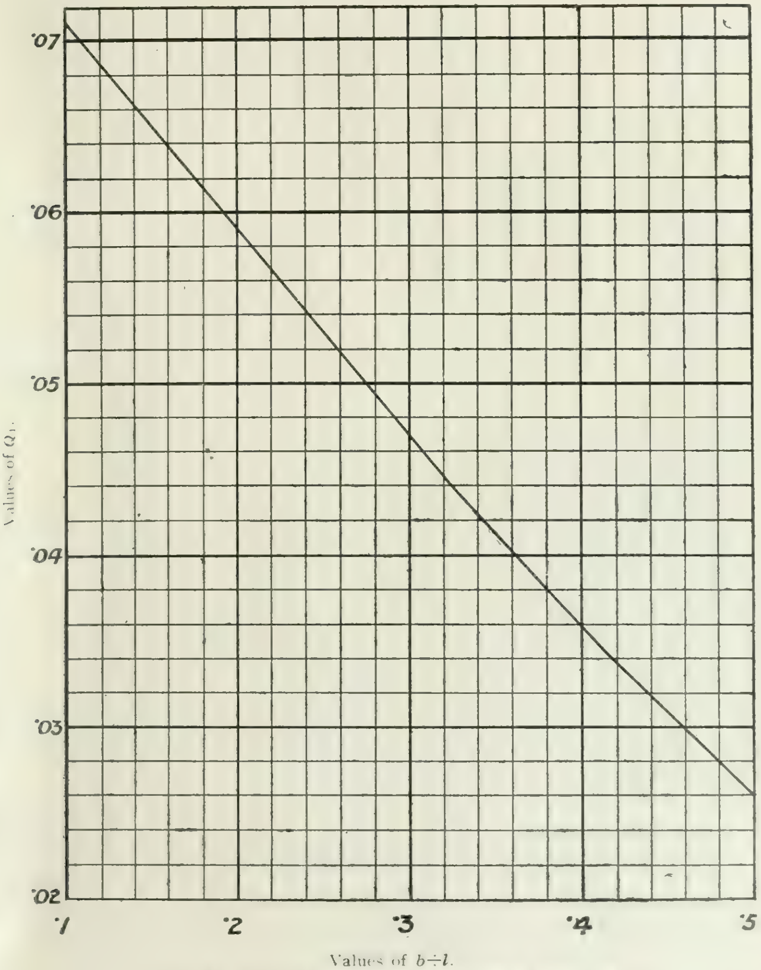


FIG. 19 DIAGRAM FOR BENDING MOMENTS IN FOOTINGS.

From *Fig.* 19 we see that $Q_1 = 0 \cdot 056$

$$\therefore \text{Bending moment} = B = Q_1 W l$$
$$= 0 \cdot 056 \times 315 \times 108$$
$$= 1{,}900 \text{ kip.-in.}$$

taking $b_e = 100$ and $d = 34$, we have

$$\frac{B}{b_e d^2} = \frac{1{,}000 \times 1{,}000}{100 \times 34 \times 34}$$
$$= 16 \cdot 5 \text{ lb. per sq. in.}$$

The diagram given in *Fig.* 3 shows that 0·11 per cent. will be suitable reinforcement, so that we have :

$$\text{Area of reinforcement required in 100 in.} = \frac{0 \cdot 11 \times 100 \times 34}{100}$$
$$= 3 \cdot 74 \text{ sq. in.}$$

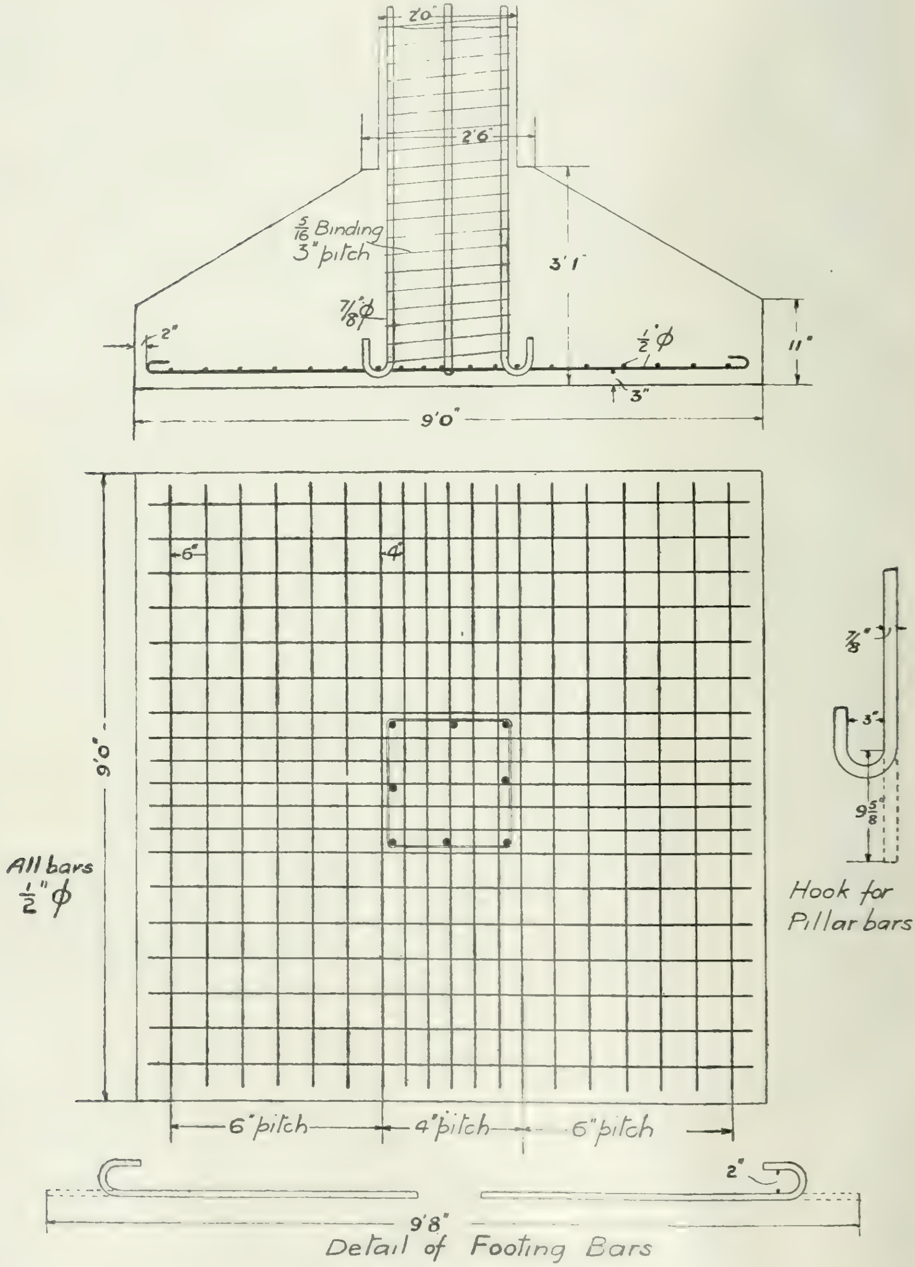


Fig. 20. Footing Detail

The area of each ½-in. bar $=0{\cdot}196$ sq. in., so that we require $\frac{3{\cdot}74}{0{\cdot}196}=19$ bars.

We will take these at 4 in. apart at the centre under the pillar, and then increase to 6 in. beyond, as shown in *Fig.* 20.

If we have not this diagram (*Fig.* 3) available, we can assume a lever arm of $0{\cdot}9d=30{\cdot}6$ in., thus obtaining

$$\text{Area of steel required}=\frac{1{,}900}{30{\cdot}6\times16}=3{\cdot}9 \text{ sq. in.}$$

Bars of small diameter are preferable in footings, because, as we shall see later, the adhesion stresses require careful consideration in footings, and small diameter bars give greater adhesion for a given cross-sectional area than large diameter. We will allow a 3-in. ledge round the column stem, and try sloping the footing off at 30° to the horizontal, the effective depth of the cantilever forming the footing thus decreasing.

We will now test the bending moment on a section 15 in. from the edge of the column, this is equivalent to taking $b=3{\cdot}5$ in our formula for the bending moment.

We then have $\frac{b}{l}=\frac{3{\cdot}5}{9}=0{\cdot}39$

For this value we have from *Fig.* 19 $Q=0{\cdot}037$. Now the effective depth at this point is 27 in., and we may assume a lever arm a equal to $0{\cdot}9d=24{\cdot}3$ in.

At the section under consideration, therefore, we have

$$\begin{aligned}\text{Bending moment}&=Q_1Wl\\&=0{\cdot}037\times315\times108 \text{ kip-in.}\\&=1{,}260 \text{ kip-in.}\\ \therefore \text{Area of steel required}&=\frac{\text{Bending moment}}{\text{Safe stress}\times\text{lever arm}}\\&=\frac{1{,}260}{16\times24{\cdot}3}=3{\cdot}24 \text{ in.}\end{aligned}$$

This is less than we have provided, so that we see that we have not sloped the footing off too steeply to provide adequate strength at the section 15 in. from the edge; further test of strength at other sections need not be made.

Bond or Adhesion Stress between Bars and Concrete. Since the footing is regarded as consisting of four short cantilevers, and, in short, heavily loaded beams, the adhesion stress has to be watched carefully, we will next calculate this adhesion stress.

We will assume that the total shearing force on each cantilever at the junction of pillar and footing is one-fourth of the value of S previously calculated—*i.e.* $=\frac{300}{4}=75$ kips. This acts over 100 in. effective breadth, in which there are 19 — ½ ϕ bars, the perimeter of each of which $=\pi\times0{\cdot}5=1{\cdot}57$ in.

Professor Talbot states that the usual formula may be employed—*i.e.*,

$$\begin{aligned}\text{Adhesion stress}&=\frac{\text{Shearing Force}}{\text{Perimeter of bars}\times\text{lever arm}}\\&=\frac{75\times1{,}000}{19\times1{\cdot}57\times30{\cdot}6}\\&=82{\cdot}3 \text{ lb. per sq. in.}\end{aligned}$$

This is less than the value 100 lb. per sq. in. allowed by regulation **42***a*, if the ends of the bars are hooked.

Shear Reinforcement.—Professor Talbot's experiments show that the critical section as regards shear is that obtained by drawing a line at 45° from the edge of the pillar to the centre of the reinforcement—*i.e.*, along the lines *GHJK*, *Fig.* 18.

The shearing force to be considered as acting on this critical section is that outside this line.

In our case $GH = 24 + 2 \times 34 = 92$ in.

$$\therefore \text{ shearing force to be considered} = \frac{315(108^2 - 92^2)}{108^2}$$

$$= \frac{315 \times 200 \times 16}{108 \times 108}$$

$$= 86{\cdot}5 \text{ kips}$$

Justification for this method of treatment in accordance with the regulation can be found in regulation **18**, which states that :

> " For calculating the resistance moment, the angle of dispersion of a point load through hard filling and concrete shall not be taken at more than 45 degrees from the vertical."

At the point under consideration, the effective depth is 12·5 in., so that the lever arm a may be taken as 11 in., and the breadth is the perimeter $GHJK$.

$$\therefore \text{ Diagonal tension stress in concrete due to shear} = \frac{S}{a\,b}$$

$$= \frac{86{\cdot}5 \times 1{,}000}{4 \times 92 \times 11}$$

$$= 21{\cdot}4 \text{ lb. per sq. in.}$$

This is much less than the 60 lb. per sq. in. allowed, so that no special shear reinforcement need be provided by the regulations.

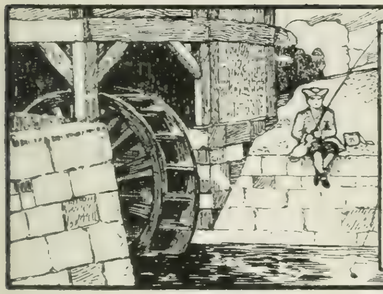
We are now ready to make the detail drawing shown in *Fig.* 20.

The hooked ends of the bars have to be made in accordance with regulation **48*b***, according to which the inner diameter of the hooks shall be at least *four times* the diameter of the bar, except when it fits over a main reinforcing bar, when it *may* be equal to the diameter of the bar ; the length of the straight part beyond the end of the curve shall be at least *four times* the diameter of the bent bar.

We have provided an end cover of 2 in. beyond the ends of the hooks, although the regulations would allow a smaller cover, since regulation **139** specifying a 2-in. cover refers only to bars anchored otherwise than by hooks. The spacing of the horizontal bars at the centre requires slight adjustment to allow the pillar bars to pass over them.

It is always desirable to indicate on the drawings the length of bars to be provided before the hook is made. This facilitates taking out the quantity of steel for estimating, and saves mistakes in erection.

We will deal in the next article with the design of a reinforced concrete retaining wall.

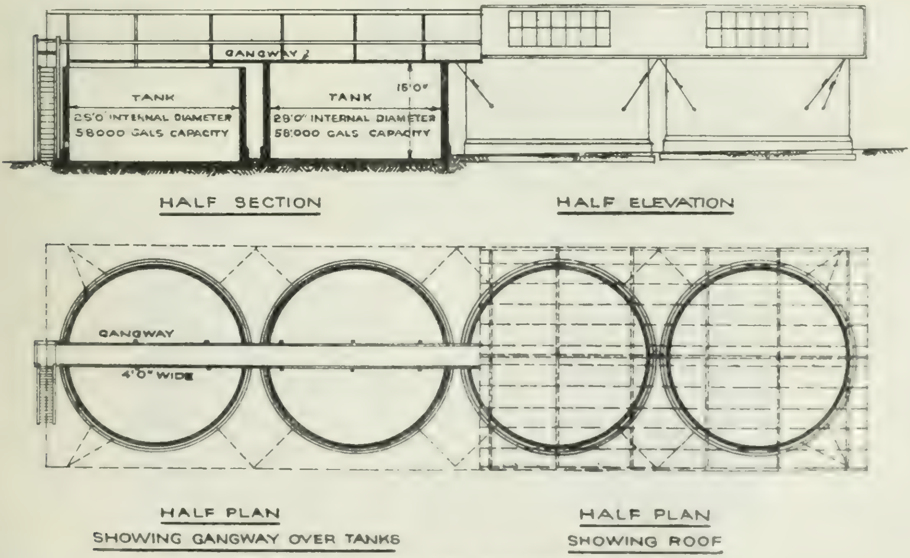


REINFORCED CONCRETE LINSEED SILO & LINSEED OIL TANKS AT PARRAMATTA, NEW SOUTH WALES.

By ARTHUR J. HART, M.Inst.C.E., M.C.I.

The following particulars of a Reinforced Concrete Linseed Silo and some Linseed Oil Tanks will probably be of interest to many of our readers.—ED.

THE one time administrative centre and Government seat of New South Wales, the town of Parramatta, distant about fifteen miles from Sydney, has much of interest centred about it reminiscent of the early colonial days in Australia. With the transfer of the Government administration to Sydney, Parramatta, became relegated to the background, and for many years has scarcely increased in population, and possesses the quiet air of an English country town of 5,000 inhabitants.

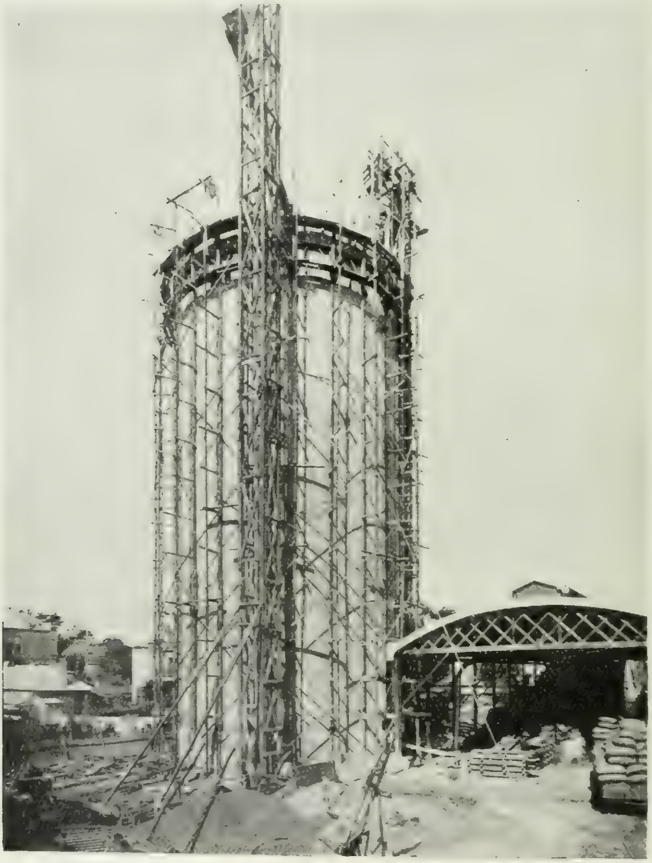


DETAILS OF LINSEED OIL TANKS, PARRAMATTA, AUSTRALIA.

The manufacture of linseed oil and cake has for many years been carried on at this place by Messrs. Meggitt, Ltd., but the energetic advertising policy carried on by this firm since its reconstruction some three years ago has again brought the name of the old township prominently before the public eye.

As linseed has not yet been grown in Australia in any quantity, it has been necessary to import the seed from Calcutta, and as it was found that the cost of the seed varied at different times of the year owing to various causes, it was decided to extend the seed storage capacity of the mill considerably, so that advantage could be taken of favourable markets to purchase and store the seed until it was required for use.

The linseed is imported and arrives at the mill in bags, and before the silo later described herein was constructed as much of the seed as was possible was stored in the square brick silo shown in the illustrations, and the balance was stacked in the bags. It was reckoned that by building increased storage capacity and by emptying the bags straight from the trucks into the storage silos a great economy could be effected, as the cost of stacking and handling bagged seed is about 2s. 6d. per ton, whereas it was computed that the cost of handling and discharging into the silo direct would not exceed 4½d. per ton.



Linseed Storage Silo in course of construction, Parramatta, Australia.

A scheme was then drawn out for the construction of a row of circular reinforced concrete silos each of 100,000 bushels capacity, and the first of these has now been built, and the conveyor tunnel beneath it arranged to connect up on either side with the silos to be added at a later date.

Unlike the usual wheat storage scheme, no provision is necessary for the grading of the grain, and the silo is therefore constructed as one single bin 100 ft. high above ground and 40 ft. internal diameter. This is certainly the largest single reinforced concrete bin yet constructed south of the Equator, and the work is therefore of more than usual interest.

The bursting pressures on the silo walls were calculated by means of Janssen's formulæ, and the conical floor at the bottom of the bin was finished with a steel float to an angle of 45 degrees. Examination of the interior of the silo after a recent emptying showed this angle to be quite as steep as was necessary, the seed having left the concrete perfectly cleanly.

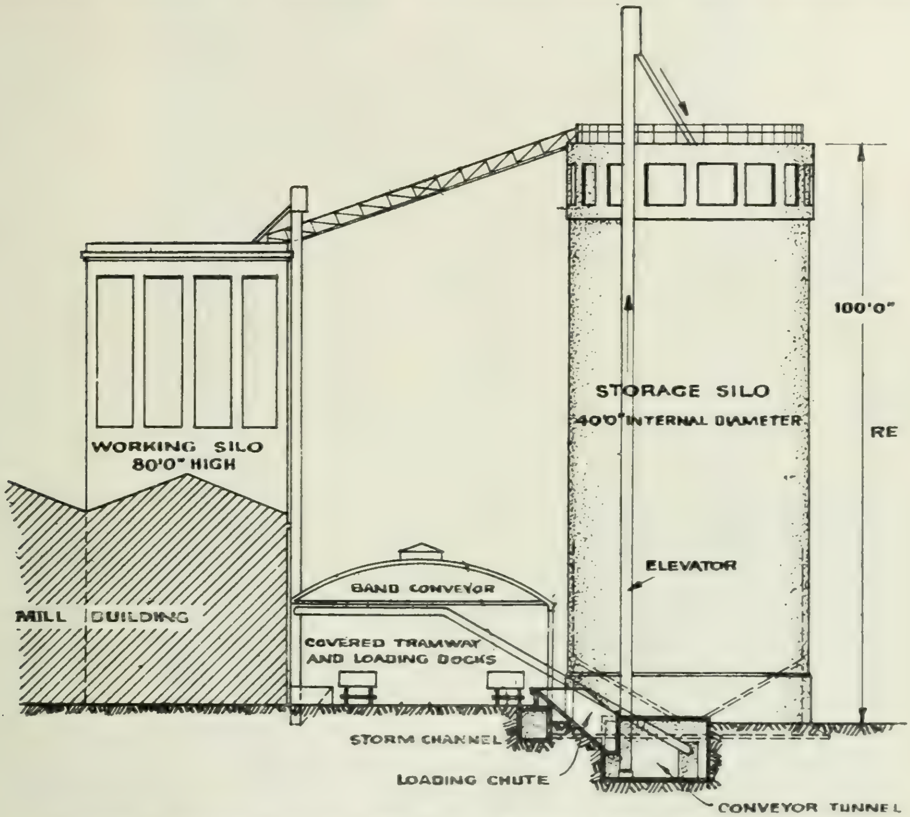
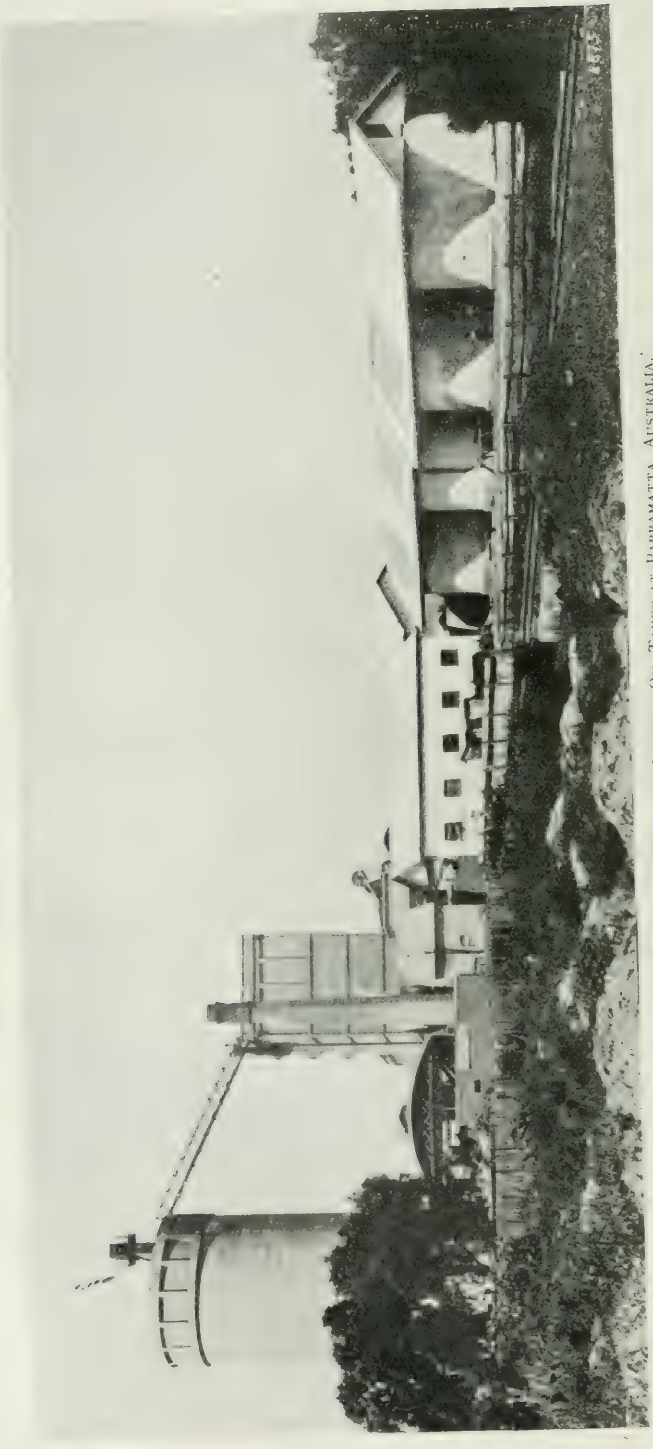


Diagram of Reinforced Concrete Linseed Silo and adjacent Mill, Parramatta, Australia.

The linseed is discharged from this storage silo on to a conveyor band by means of which it is elevated again into the brick silo, which is used to supply the daily needs of the mill. The future storage silos will also feed this same brick silo by means of the conveyor band placed in the conveyor tunnel, shown underneath the silo in the diagram.

LINSEED OIL STORAGE TANKS.

When the seed passes through the mill it is first crushed between rollers and afterwards heated in a steam-jacketed copper. On being withdrawn from this last it is placed in moulds and subjected to hydraulic pressure, by means of

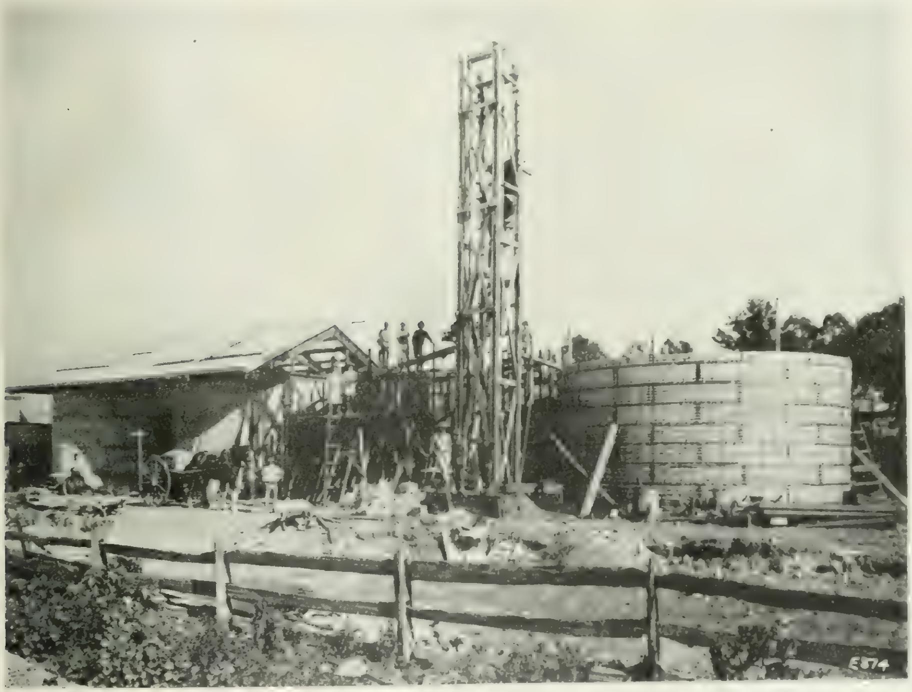


General View of Linseed Silo and Linseed Oil Tanks at Parramatta, Australia.

which the oil is abstracted, the yield of oil being about 33 per cent. by weight of the seed. The compressed seed cake which is left is the linseed oil cake so much used by farmers.

The oil is drained from the presses into settling tanks, and after remaining there for some hours it passes on to the maturing tanks, where it remains until clarified and mature.

Owing to the difficulty of obtaining steel plates, these maturing tanks have been constructed in reinforced concrete lined with galvanised corrugated iron riveted and sweated at the joints, which, with careful manufacture, have proved so satisfactory in twelve months of use that the construction of additional similar tanks has recently been undertaken.

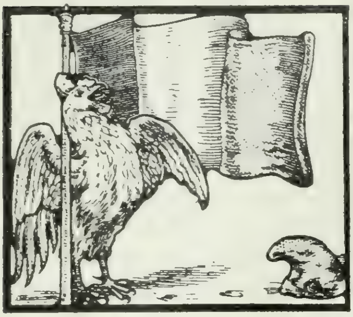


Linseed Oil Tanks in course of construction, Parramatta, Australia.

In constructing the tanks the reinforced concrete floors were first poured, after which the galvanised iron floor was laid and riveted. The complete galvanised iron tanks were then built and the reinforcement placed around them before the concrete walls were poured. After the concrete had been placed the exposed work was finished off with cement plaster applied with a wood float.

The tanks are covered with galvanised iron and timber roofs, open to the air on the underside, and with large areas of glazing to assist in the more speedy clarification of the oil.

Indented steel bars were used throughout the work as reinforcement.



THE CALCULATION OF REINFORCED CONCRETE STRUCTURES. — RAPID METHODS APPLICABLE TO BEAMS.

By **N. DE TEDESCO,**
Civil Engineer, Ecole Centrale, Paris.

The following is in continuation of an article which appeared in our issue of December, 1916. By an oversight the two diagrams, Figs. 1 and 2, were omitted in the previous article to which they have reference.—ED.

In the preceding article the rational coefficients, α, β, γ, δ, and ϕ, have been indicated for the rapid calculation of reinforced concrete slabs in such a manner that the working stress of the concrete and of the steel does not exceed the prescribed limits. These coefficients are based on the following values:—

$$m=15 \qquad t=1600 \qquad c=600$$

The following table also gives the value of these coefficients for other limits of c between 400 and 800 lbs. per sq. in.

c	α	β	γ	δ	ϕ	$\frac{a}{d}$
	$\frac{mc}{mc+t}$	$2c\alpha\,(3-\alpha)$	$\frac{6c\alpha}{t}$	$\frac{3}{8}mc\,(3-\alpha)$	$\sqrt{1-\frac{2mc}{3t}}$	$1-\frac{\alpha}{3}$
lb.						
400	0·273	595	0·041	3,636	0·867	0·909
500	0·319	855	0·060	4,468	0·829	0·894
600	0·360	1,140	0·081	5,280	0·790	0·880
700	0·396	1,443	0·104	6,076	0·750	0·868
800	0·428	1,760	0·129	6,859	0·707	0·857

It will be remembered that:—

$$n=\alpha d\ ;\ B=\beta d^2\ ;\ A_t=\gamma d=\frac{B}{at}\ ;\ A_c=\frac{B-\beta d^2}{\delta d}\ ;\ d^1=\phi d$$

Rectangular Beams. -The rectangular beams only differ from the slabs by the fact that their width b is small compared to their height d_s.

It will also be necessary to treat in the same manner as rectangular beams the T-beams, the slabs of which are working in tension. This is the case where the sections of a beam are considered as subjected to a negative bending moment, or when the horizontal slabs on either side of the beam do not form a floor but a ceiling.

Although the methods of calculation of rectangular beams are the same as those which have been indicated for the slabs, it is necessary, in order to make the matter quite clear, that a few examples should be given, inasmuch as in the actual case the width b or the thickness d_s are not determined.

Find the width, the height and the reinforcement of a rectangular beam, working under a uniform load of 700 lbs. per ft. on a span of 17 ft.

We shall assume at first $b=8$ in., $d=20$ in.

$$\text{Dead weight } \frac{8}{12} \times \frac{20}{12} \times 156 \text{ lbs.} = 8 \times 20 \times \frac{13}{12} = 174 \text{ lbs.}$$

$$\text{Total load} = 700 + 174 = 874$$

$$B = \frac{874 \times \overline{17}^2 \times 12}{8} = 378879$$

$$378879 \times \frac{12}{8} = 568319$$

$$d = \sqrt{\frac{B}{\beta}} = \sqrt{\frac{568319}{1140}} = 22{\cdot}33 \text{ in.}$$

—namely, for a width of 1 ft. instead of 8 in.

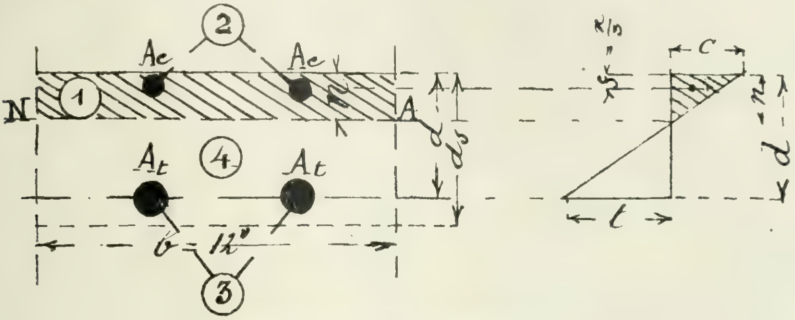


FIG. 1.
(Referred to in previous article.)

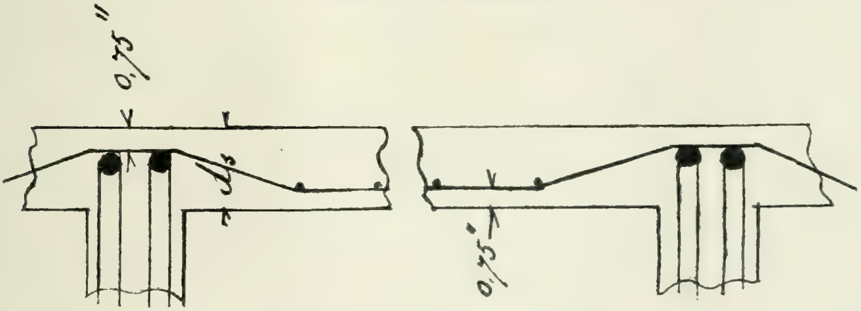


FIG. 2.
(Referred to in previous article.)

The assumed height, $d = 20$ in., is therefore too small. We must therefore increase this height to 21 in., for instance, and b to 12 in. We shall have in succession:

$$\text{Total load} = 12 \times 21 \times \frac{13}{12} + 700 = 973$$

$$B = \frac{973 \times \overline{17}^2}{8} \times 12 = 421796$$

$$d = \sqrt{\frac{421796}{1140}} = 19{\cdot}24$$

$$d_s = 19{\cdot}24 + 1{\cdot}76 = 21 \text{ in.}$$

$$A_t = 19{\cdot}24 \times {\cdot}081 = 1{\cdot}56$$

Verification.

$$n = {\cdot}36 \times 19{\cdot}24 = 6{\cdot}93$$

$$\frac{12}{2} \times 6{\cdot}93^2 = 15 \times 1{\cdot}56\ (19{\cdot}24 - 6{\cdot}93) = 23{\cdot}4 \times 12{\cdot}31 = 288{\cdot}05$$

$$288{\cdot}15 - 288{\cdot}05 = 0{\cdot}10$$

$$I = \frac{12}{3} \times 6{\cdot}93^3 + 15 \times 1{\cdot}56 \times 12{\cdot}31^2 = 1331{\cdot}25 + 3545{\cdot}94 = 4877{\cdot}19$$

$$\frac{B}{I}=\frac{421796}{4877{\cdot}19}=86{\cdot}34$$

$$c=86{\cdot}34\times6{\cdot}93=598{\cdot}34$$

$$t=86{\cdot}34\times12{\cdot}31\times15=15941{\cdot}77$$

Bars in compression.—If it is necessary to keep the scantlings of 8 in. × 20 in., which we have found insufficient for the span and the superload indicated above, it will be necessary to provide for bars working in compression. This will be all the easier if we follow the example of certain constructors who provide bars in the compressed area for constructional purposes in order to provide a better method of fixing the stirrups, or round bars, and to resist negative bending moments due to partial fixing of the beam. For the scantlings of 18 in. × 20 in. the preceding calculations have given us $B=378879$, corresponding to 568319 for 1 ft. of width. Applying the formula we have:

$$A_c=\frac{B-3d^2}{\delta d}$$

$$C=12\text{ in.}\qquad A_c=\frac{568319-1140\times18^2}{5280\times18}=2{\cdot}09$$

$$\text{and for } C=8\text{ in.}\qquad A_c=2{\cdot}09\times\frac{8}{12}=1{\cdot}393$$

namely, for $b=8$ in. $A_c=2{\cdot}09\times\frac{8}{12}=1{\cdot}393$

To determine A_t we shall provide:—

$$a=d-f=d-\frac{n}{3}=18-0{\cdot}36\times\frac{18}{3}=15{\cdot}84$$

$$A_t=\frac{B}{at}=\frac{378879}{15{\cdot}84\times16000}=1{\cdot}49$$

Verification.

$$n={\cdot}36\times18=6{\cdot}48;\quad n-f=6{\cdot}48-\frac{6{\cdot}48}{3}=4{\cdot}32$$

$$d-n=18-6{\cdot}48=11{\cdot}52$$

$$I=\frac{8\text{ in.}}{3}\times6{\cdot}48^3+15\times1{\cdot}393\times\overline{4{\cdot}32}^2+15\times1{\cdot}49\times\overline{11{\cdot}52}^2$$

$$I=725{\cdot}33+389{\cdot}89+2966{\cdot}07=4081{\cdot}29$$

$$\frac{B}{I}=\frac{378879}{4081}=92{\cdot}81$$

$$c=92{\cdot}81\times6{\cdot}48=601{\cdot}40$$

$$t=92{\cdot}81\times11{\cdot}52\times15=16037$$

To facilitate the determination of the scantlings of beams the following table will be found useful. It gives the moment of resistance and the section of the reinforcement for various theoretical heights d and widths $b=12$ in.

				I. $A_c=0$		II. $A_c=\frac{A_t}{4}$			III. $A_c=\frac{A_t}{2}$			IV. $A_c=A_t$	
No.	d	d_s	Own Weight	A_t	B_0	A_c	A_t	B_1	A_c	A_t	B_2	$A_c=A_t$	B_3
	in.	in.	lb.	sq. in.		sq. in.	sq. in.		sq. in.	sq. in.		sq. in.	
1	12	13·5	176	0·972	164,160	0·27	1·08	181,134	0·60	1·20	201,917	1·56	262,656
2	16	17·5	228	1·296	291,840	0·36	1·43	322,016	0·80	1·60	358,004	2·08	466,942
3	20	21·5	280	1·630	456,000	0·45	1·79	503,150	1·00	2·00	560,880	2·60	729,600
4	24	25·5	332	1·944	656,640	0·54	2·15	724,536	1·20	2·40	807,667	3·12	1,050,624
5	28	29·5	384	2·268	893,760	0·63	2·51	986,174	1·40	2·80	1,099,325	3·64	1,430,000
6	32	34·0	442	2·592	1,167,360	0·72	2·87	1,288,005	1·60	3·20	1,435,853	4·16	1,867,776
7	36	38·0	494	2·916	1,477,440	0·81	3·23	1,630,207	1·80	3·60	1,817,252	4·68	2,363,904
8	40	42·0	546	3·240	1,824,000	0·90	3·59	2,012,601	2·00	4·00	2,243,520	5·20	2,918,400
9	44	46·0	598	3·500	2,207,040	0·99	3·95	2,435,203	2·20	4·40	2,714,060	5·72	3,531,200
10	48	50·0	650	3·884	2,626,560	1·08	4·31	2,898,146	2·40	4·80	3,230,669	6·24	4,202,496

It must be remembered that for any particular width b varying from 1 ft. it is sufficient to multiply by $\frac{b}{12}$ the relative figures to the various values. This table has been calculated for:—

$$m=15;\ c=600;\ t=16000$$

$$\alpha={\cdot}36;\ \beta=1140;\ \gamma={\cdot}081;\ \delta=5280$$

$$aA_t={\cdot}88\,d\times16000=14080\,d$$

$$B_0=1140\,d^2;\ A_t=\frac{B_0}{14080\,d}$$

$$B_1=1{\cdot}1034\,B_0;\ A_t=\frac{B_1}{14080\,d};\ A_c=\frac{A_t}{4}$$

$$B_2=1{\cdot}2307\,B_0;\ A_t=\frac{B_2}{14080\,d};\ A_c=\frac{A_t}{2}$$

$$B_3=1{\cdot}60\,B_0;\ A_t=\frac{B_3}{14080\,d};\ A_c=A_t$$

The coefficients. 1·1034, 1·2307, 1·60, have been obtained by combining the two equations:—

Hence: $$A_c=\frac{B-1140\,d^2}{5280d}\ \text{and}\ A_t=\frac{B}{14080\,d}$$

$$B=\frac{1140\,d^2}{1-0{\cdot}375\frac{A_c}{A_t}}=\frac{B_0}{1-{\cdot}375\frac{A_c}{A_t}}$$

This table can be verified and the manner in which it must be used is indicated by the following example:—

Calculate a rectangular beam supporting a uniformly distributed load of 700 lbs. per ft. and having a span of 17 ft.

Leaving out of consideration first the dead weight we shall have:

1°. $A_c=0$ $$B=\frac{700\times17^2\times12}{8}=303450$$

Firstly. $$A_c=0$$

We shall choose in the column B_c the moment which is the next greatest, namely, 456000, corresponding to $d=20$ for $A_t=1{\cdot}63$.

But, as the dead weight is 280 lbs. per ft., we must deduct 456000, the bending moment due to the dead weight.

$$\frac{280\times17^2\times12}{8}=121380$$

We only dispose in reality of the following:

$$456000-121380=334620$$

The width to be provided will therefore be:

$$b=\frac{303450}{33462}=10{\cdot}882$$

We will naturally provide for $b=11$

$$A_t=\frac{10{\cdot}882}{12}\times1{\cdot}63=1{\cdot}478$$

We will choose, for instance, 4 bars $\frac{11}{16}$ in. diameter.

Verification. $$C=10{\cdot}882;\ d=20;\ n={\cdot}36\times20=7{\cdot}20$$

$$d-n=20-7{\cdot}20=12{\cdot}80;\ m\,A_t=15\times1{\cdot}478=22{\cdot}17$$

$$\left.\begin{aligned}I=\frac{10{\cdot}882}{3}\times7{\cdot}20^3&=1354\\+22{\cdot}17\times12{\cdot}80^2&=3632\end{aligned}\right\}4986$$

$$B=303450+\frac{280\times10{\cdot}882}{12}\times\frac{17^2\times12}{8}=413518$$

$$\frac{B}{I}=\frac{413518}{4986}=82{\cdot}93$$
$$c=82{\cdot}93\times7{\cdot}20=597$$
$$t=82{\cdot}93\times12{\cdot}80\times15=15923$$

Secondly.

$$A_c=\frac{A_t}{4}$$

$$\text{for } d=20\,;\ B_1=\frac{5}{315}\,;\ A_t=1{\cdot}79\,;\ A_c={\cdot}45$$

We dispose therefore of:

2. $A_c=\dfrac{A_t}{4}$

$$d=20\,;\ B_1=503150:\ A_t=1{\cdot}79\,;\ A_c={\cdot}45$$
$$n={\cdot}36\times20=7{\cdot}20\,;\ n-f=\tfrac{2}{3}\times7{\cdot}20=4{\cdot}80$$
$$503150-121380=381770$$
$$C=\frac{303450}{381770}\times12=9{\cdot}53$$
$$A_t=9{\cdot}53\times1{\cdot}79=1421\,;\ mA_t=15\times1421=21{\cdot}32$$
$$A_c=9{\cdot}53\times{\cdot}45={\cdot}36\,;\ mA_c=15\times{\cdot}36=5{\cdot}4$$
$$\left.\begin{array}{r}I=\dfrac{9{\cdot}53}{3}\times7{\cdot}20^3=1185{\cdot}70\\ +5{\cdot}4\times\overline{4{\cdot}80}^2=\ 124{\cdot}40\\ +21{\cdot}32\times\overline{12{\cdot}80}^2=3493{\cdot}00\end{array}\right\}4803{\cdot}10$$
$$B=303450+280\times\frac{9{\cdot}53}{12}\times\overline{17}^2\times\frac{12}{8}=399846$$
$$\frac{B}{I}=\frac{399846}{4803{\cdot}1}=83{\cdot}25$$
$$c=83{\cdot}25\times7{\cdot}20=599{\cdot}40$$
$$t=83{\cdot}25\times12{\cdot}80\times15=15990$$

Thirdly.

$$A_c=\frac{A_t}{2}\ \text{for } d=20$$
$$B_2=560880$$
$$3''\ A_c=\frac{A_t}{2}\ d=20\,;\ B_2=560880\,;\ A_t=2\,;\ A_c=1$$
$$560880-121380=439500$$

Remark. The numbers of the above table are on the assumption that the compressed bars are placed at a distance $\dfrac{{\cdot}36d}{3}={\cdot}12d$, but if these bars are placed higher, if possible, the resistance will be slightly increased.

$$C=\frac{303450}{439500}\times12=8{\cdot}285$$
$$A_c=\frac{8{\cdot}285}{12}\times1={\cdot}69\,;\ A_t=\frac{8{\cdot}285}{12}\times2=1{\cdot}38$$
$$m\ A_c=15\times{\cdot}69=10{\cdot}35\,;\ m\ A_t=15\times1{\cdot}38=20{\cdot}70$$
$$n={\cdot}36\times20=7{\cdot}20\,;\ n-f=\frac{2}{3}\times7{\cdot}20=4{\cdot}80$$

Verification.

$$\left.\begin{array}{r}I=\dfrac{8{\cdot}285}{3}\times\overline{7{\cdot}20}^3=1031\\ +10{\cdot}35\times\overline{4{\cdot}80}^2=238\\ +20{\cdot}70\times\overline{12{\cdot}80}^2=3391\end{array}\right\}4660$$
$$B=303450+\frac{280\times8{\cdot}208}{12}\times17^2\times\frac{12}{8}=387253$$

$$\frac{B}{L}=\frac{387253}{4660}=83{\cdot}10$$

$$c=83{\cdot}10\times 7{\cdot}20=598{\cdot}32$$

$$t=83{\cdot}10\times 12{\cdot}80\times 15=15955$$

4^{0} $A_c=A_t.$ $\quad d=20\,;\ B_3=729600\,;\ A_c=A_t=2{\cdot}60$

$$729600-121380=608220$$

$$C=\frac{303450}{608220}=5{\cdot}989$$

$$A_c=A_t=\frac{2{\cdot}60\times 5{\cdot}989}{12}=1{\cdot}30$$

$$m\ A_c=m\ A_t=15\times 1{\cdot}30=19{\cdot}50$$

Verification.

$$\left.\begin{aligned}\frac{5{\cdot}989}{3}\times 7{\cdot}20^3&=745\\ +19{\cdot}50\left(\overline{4{\cdot}80}^2+12{\cdot}80^2\right)&=3644\end{aligned}\right\}4389$$

$$B=303450+280\times\frac{5{\cdot}989}{12}\times\overline{17}^2\times\frac{12}{8}=364029$$

$$\frac{B}{I}=\frac{364029}{4389}=82{\cdot}94$$

$$c=82{\cdot}94\times 7{\cdot}20=597$$

$$t=82{\cdot}94\times 12{\cdot}80\times 15=15924$$

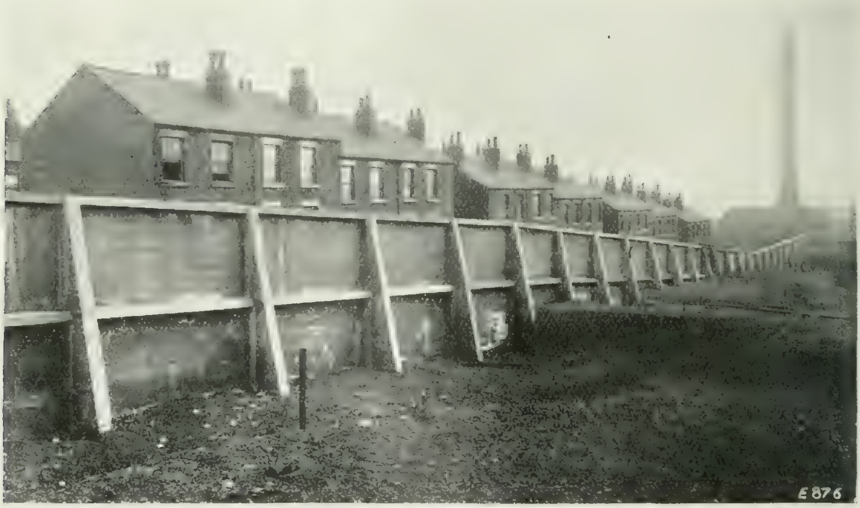
We dispose therefore of four solutions to the given problem, and it is possible to compare the cost prices from the following quantities:

		Concrete.		*Reinforcement.*
1^{0}	B_0 $(A_c=o)$	$10{\cdot}882\times 22=240$ sq. in.		$1{\cdot}48$ sq. in.
2^{0}	B_1 $\left(A_c=\frac{A_t}{4}\right)$	$9{\cdot}53\times 22=210$	,,	$1{\cdot}42+{\cdot}36=1{\cdot}78$
3^{0}	B_2 $\left(A_c=\frac{A_t}{2}\right)$	$8{\cdot}285\times 22=182$	,,	$1{\cdot}38+{\cdot}69=2{\cdot}07$
4^{0}	B_3 $(A_c=A_t)$	$5{\cdot}989\times 22=132$	,,	$1{\cdot}30+1{\cdot}30=2{\cdot}60$

A COAL STORE AT LEEDS.

The accompanying photographs show a coal store and gantry recently erected of reinforced concrete for the City of Leeds Electric Light Department at South Accommodation Road.

The work consisted in the erection of a retaining wall on three sides of the existing yard, the remaining side being formed by brick walls of adjoining structures. An elevated gantry or viaduct in reinforced concrete runs through the middle of the coal store for the purpose of loading and unloading the coal by means of wagons and cranes.



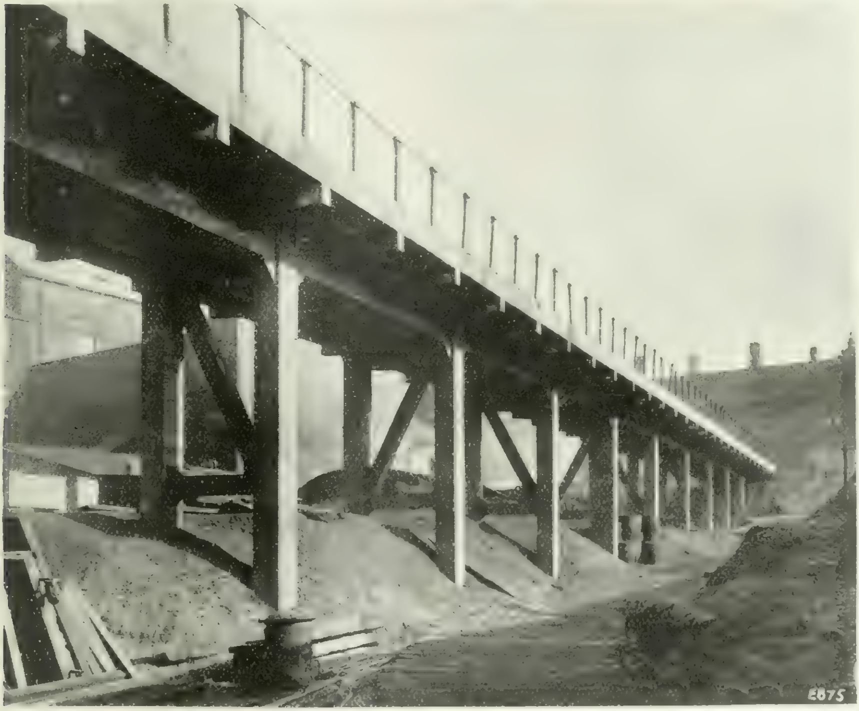
A Reinforced Concrete Retaining Wall, Coal Store, Leeds Electric Light Department.

The whole of the work was carried out in accordance with the requirements and instructions of Mr. G. W. Atkinson, M.S.A., and the plans for the reinforced concrete work were executed by Messrs. Edmond Coignet, Ltd., of Westminster, London, S.W.

The photographs show the coal store in its present condition and containing a certain quantity of accumulated coal.

The principal dimensions and features of this work are as follows :—

A long retaining wall calculated to maintain the earth embankment of the adjoining street, and also the pressure of the coal, was constructed in bays of 14 ft. 7 in., 14 ft. 9 in., and 13 ft. 11 in., with a middle bay of 11 ft. 4 in. to form a gateway, the total length of this wall being about 319 ft. On account of the inclination of the ground the height of the wall varies between 22 ft. 6 in. at the upper portion to 24 ft. 6 in. in the middle, gradually tapering down to 18 ft. 6 in. at the lower end. This long wall is formed by means of buttresses in reinforced concrete supporting horizontal beams and panels, the thickness of the panels being only 6 in. for the lower panels and 5 in. for the upper ones. At the top of the coal store a reinforced concrete retaining wall has been constructed having a total length of 152 ft. 6 in. in bays of 15 ft. An opening through this wall at the top leads on to the gantry by means of an abutment, or earth embankment, retained by means of two parallel reinforced concrete walls 73 ft. 7 in. long, also in bays of 15 ft. span between buttresses, this wall forming return of the principal retaining wall. At the lower end of the coal store a retaining wall 38 ft. in length has been constructed. On either side of this wall there are two bays, 10 ft. wide, to enable carts to enter.



A REINFORCED CONCRETE VIADUCT, COAL STORE, LEEDS ELECTRIC LIGHT DEPARTMENT.

The gantry has a total length of 389 ft., not including the embankment. It is composed of fifteen bays of 20 ft. each, supported by reinforced concrete pillars, and an odd bay at the end of 14 ft. The height between the ground level of the coal store and the top of the rails is 24 ft. The platform, which carries two separate tracks, one for the crane and one for the wagons, or trams, has a total width of 17 ft. 6 in. over all. The rails are so arranged as to come on the top of longitudinal beams designed sufficiently strong to carry the rolling loads. On either side of the rails the platform is extended by means of cantilever beams and slabs, and the side beams are fitted with a movable standard and chains. The pillars, which have scantlings of 18 in. by 18 in., are braced together by means of horizontal and diagonal beams, in order to ensure the rigidity of the structure.

The whole of the reinforcement was carried out by means of round bars of mild steel varying between $\frac{3}{16}$ in. and $1\frac{1}{4}$ in. The buttresses and the horizontal beams were reinforced by means of straight bars tied together by stirrups, and the slabs were composed of bars arranged to form a meshwork. The pillars of the viaduct and the braces contained straight bars tied together by means of spiral ties. The main beams, however, supporting the crane track were formed by means of two steel frames or units composed of seven bars having their ends gradually bent up diagonally and hooked over a top longitudinal bar in order to form a kind of truss inside the concrete, the bent up ends of the bars being utilised to resist the shear towards each end of the beam where it is greatest. The secondary beams, however, were composed of straight top and bottom bars united together by means of stirrups of small diameter, and the reinforcement of the slab of the platform was simply composed of a meshwork of principal and secondary bars.

The reinforced concrete work was carried out by Mr. Wm. J. Turnbull, contractor, of Leeds.

CONCRETE BOATS AND MOTOR BOATS.

The following notes on Ship Building in Norway have been prepared for us by Dr. A. B. Searle. For the drawings and photographs we are indebted to Mr. G. Brockner and Messrs. Fougner.—ED.

THE fact that concrete increases in strength and hardness the longer it is immersed in water makes this material particularly suitable for the construction of boats, barges, and even larger vessels. Indeed, as long ago as 1849 a boat was built of concrete by a Frenchman in the United States and found to be exceptionally durable. During the past few years the development of concrete boats has been very rapid. The greatest advance, however, has been made by the Porsgrund Cementstöperi A/S, of Porsgrund, Norway, who, in 1915, constructed a concrete pontoon 53 ft. long, 16 ft. wide, and 7 ft. high, consisting of a deck supported by two watertight compartments. The concrete was a 1 : 3 mixture with a plentiful supply of small stones. The walls were 2 in. thick. The mixture was cast between double shutters and only required two days for its completion, twenty men being employed. The work was so well done that the pontoon was quite watertight without any further dressing or finishing being required.

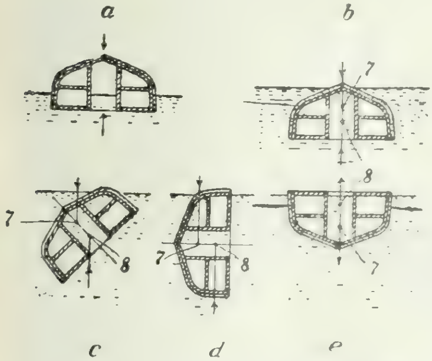


FIG. 1. DIAGRAM SHOWING HOW VESSEL RIGHTS ITSELF AFTER LAUNCHING.

Notwithstanding this success, several improvements were called for; the use of double shutters was inconvenient, there was some uncertainty as to the reinforcement being kept in its proper place, and the casting required exceptional care and skill. After due consideration Mr. Harold Alfsen, the manager of the works, decided to construct future boats upside down and to use only an internal core instead of the double shuttering. This greatly facilitated the construction, but necessitated inverting the vessel before it could be used. This problem was solved in the following ingenious manner, for which letters patent have been granted: The hull is launched in a perfectly stable position, *a* (Fig. 1),

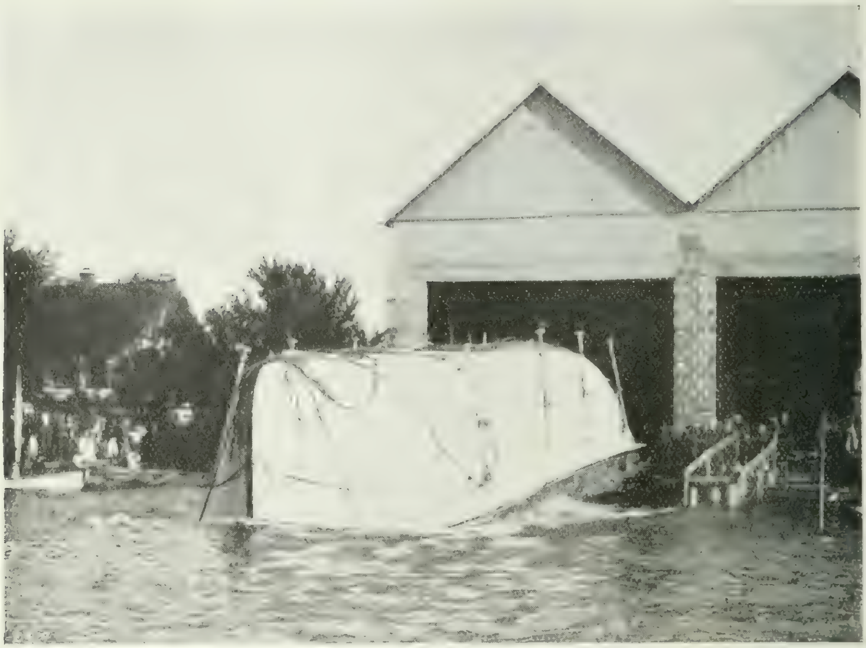


Fig. 2. Inverted Vessel Entering the Water.

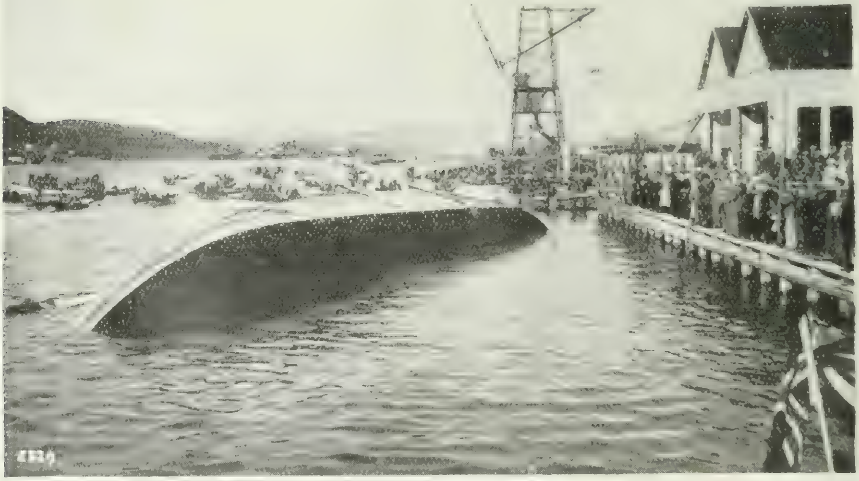


Fig. 3. Vessel Commencing to Right Itself

and water is allowed to enter the centre and the two upper compartments by men in boats alongside opening air-cocks leading to these parts of the vessel so that it attains to position *b*. This position is unstable, as the centre of gravity of the hull lies near point 7, with the result that the vessel begins to turn over—slowly at first, then gradually more rapidly, and, finally, slowly, until the vessel has fully righted itself. The water is then pumped out in the customary manner and the launching of the vessel is complete. The process of launching is also shown in the photographs reproduced herewith, *Fig.* 2 showing the vessel entering the water in an inverted position, *Fig* 3 showing it at an early stage in the turning, *Fig* 4 when it is about half-righted, and *Fig.* 5 giving a view of the completely righted vessel.

These photographs show a motor-boat of 200-ton load capacity, 20 ft. long, 9 ft. wide, and with sides 2 in. thick, designed by Messrs. Bonde and Norman,

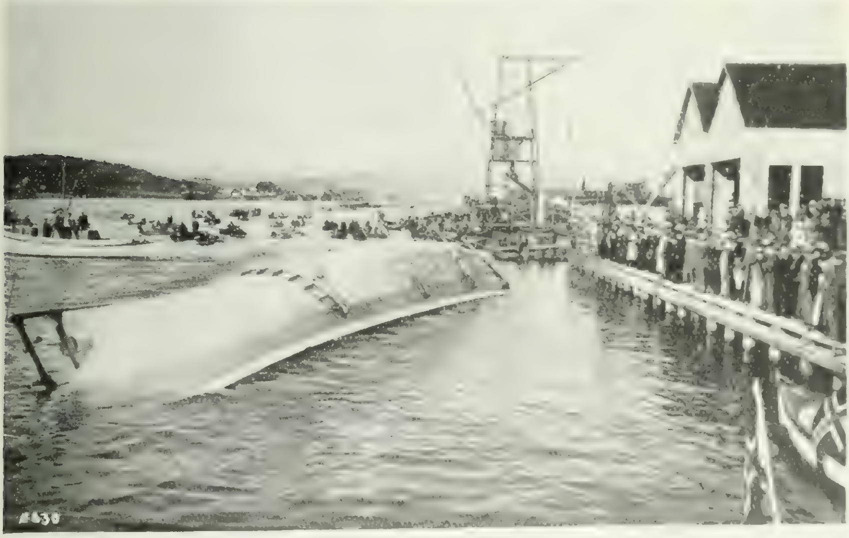


Fig. 4. Vessel Half Righted.

and built by the same firm as the pontoon, which has proved the utility of this mode of construction and launching. The core was mounted on a sliding platform or sledge, which, at the launching, was pushed into the water, taking the vessel with it. The core was easily taken to pieces and reassembled and can be used repeatedly. The reinforcement was completed before the casting was commenced, the latter requiring two days. The concrete—which was a rich mixture (1 : 2) without any stones—required the service of 40 men for the casting, this being done partly by hand and partly with the aid of compressed air. The concrete was allowed three weeks in which to harden, so that the whole time required for the construction of such a boat, including the shuttering or core and the reinforcements, is less than six weeks. No special dressing or finishing-coat was used, but the surface was smoothed after the completion of the casting.

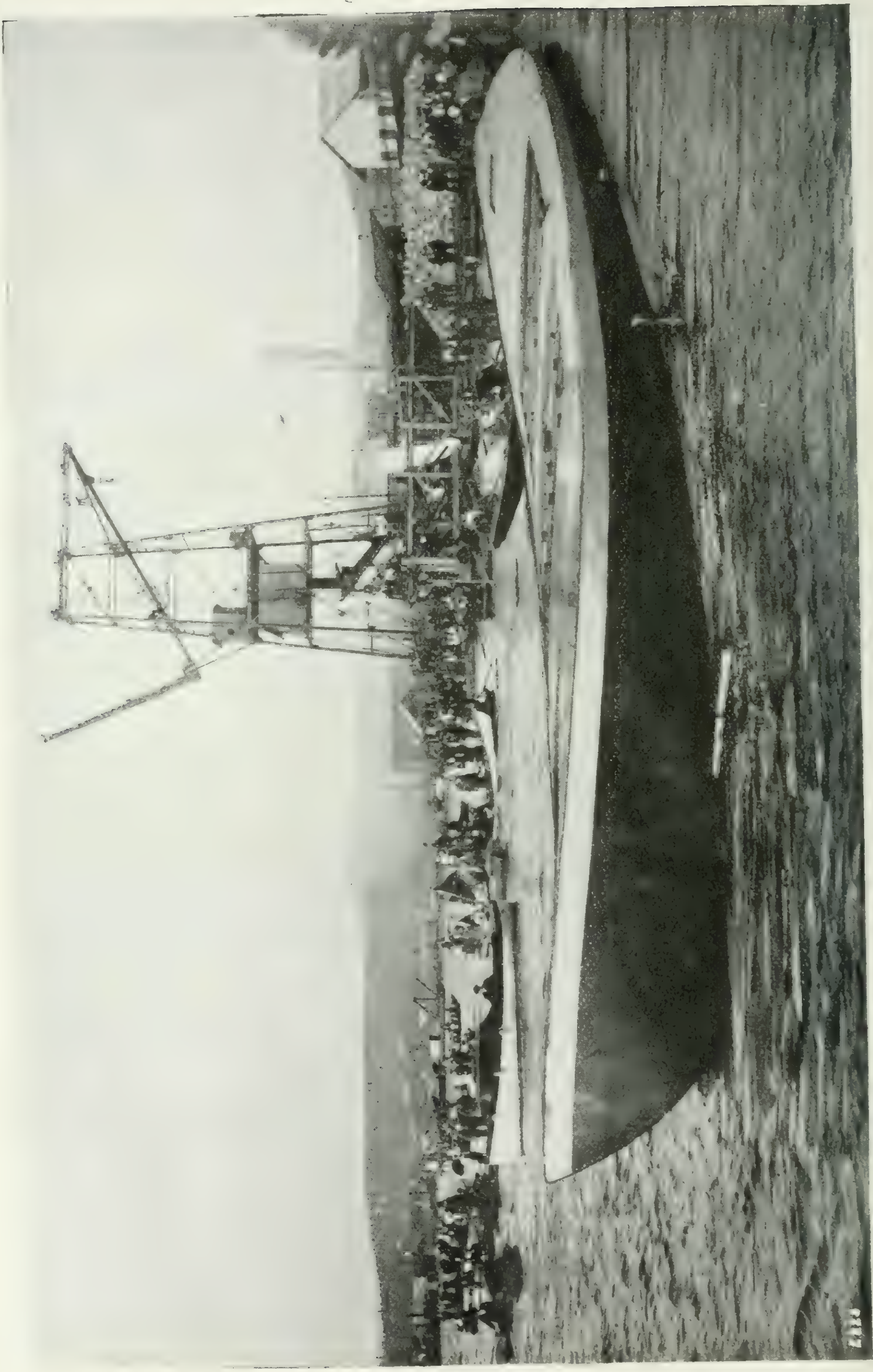


Fig. 5. Launching Completed.

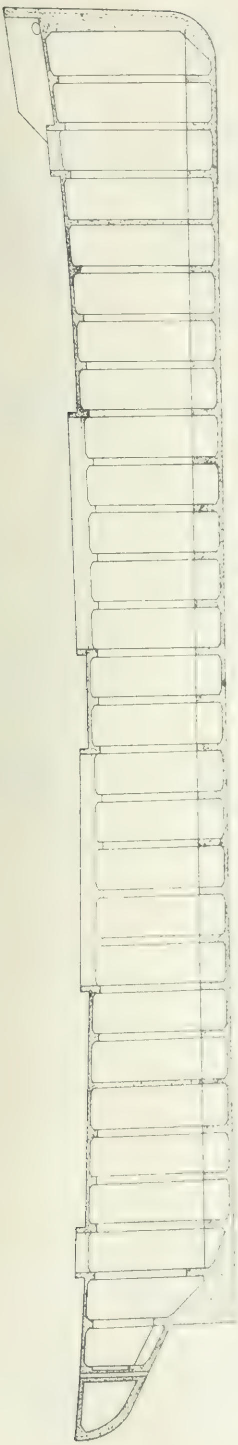


Fig. 6. Longitudinal Section of Vessel.

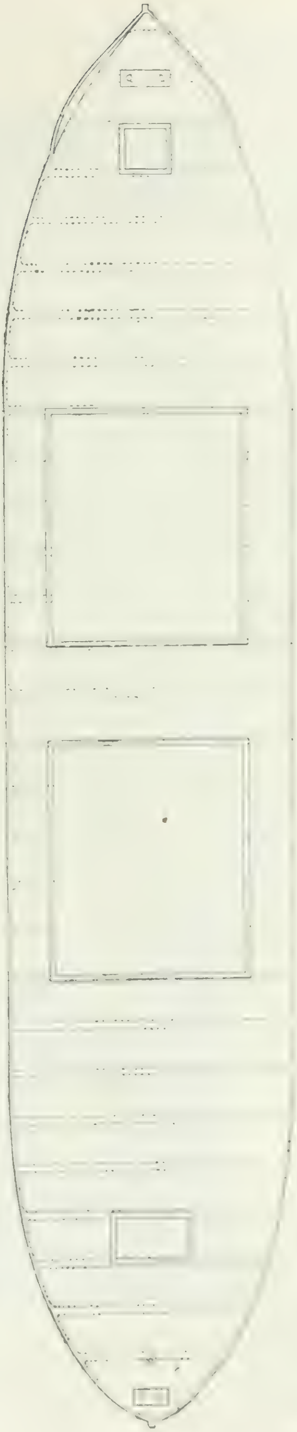


Fig. 7. Plan of Vessel.

Whilst it is difficult to show many details in small illustrations, our readers will be interested in studying carefully *Figs.* 6-9, in each of which the dimensions are stated in millimetres. *Fig.* 6 is a longitudinal section and *Fig.* 7 a plan showing the general arrangement of the reinforcement in the bottom, sides and deck of the barge. *Fig.* 8 shows the framework for rib 18, and *Fig.* 9 the reinforcement employed for this rib.

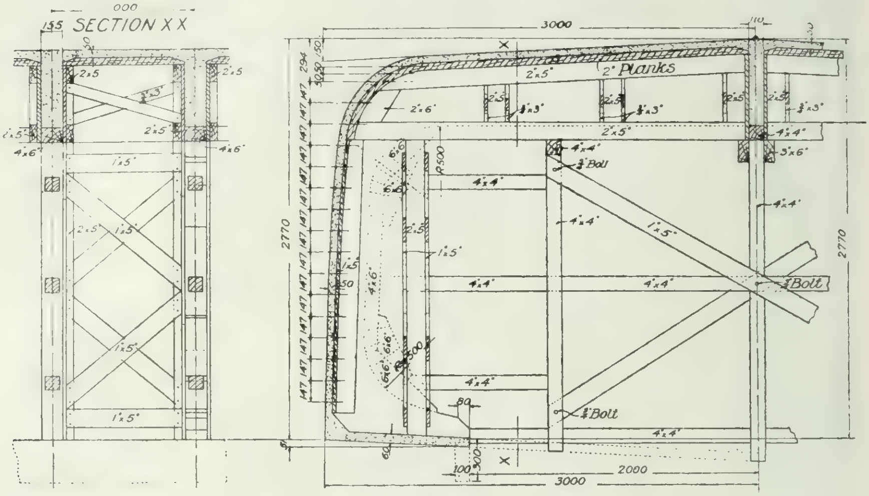


Fig. 8. Framework for Casting Rib 18.

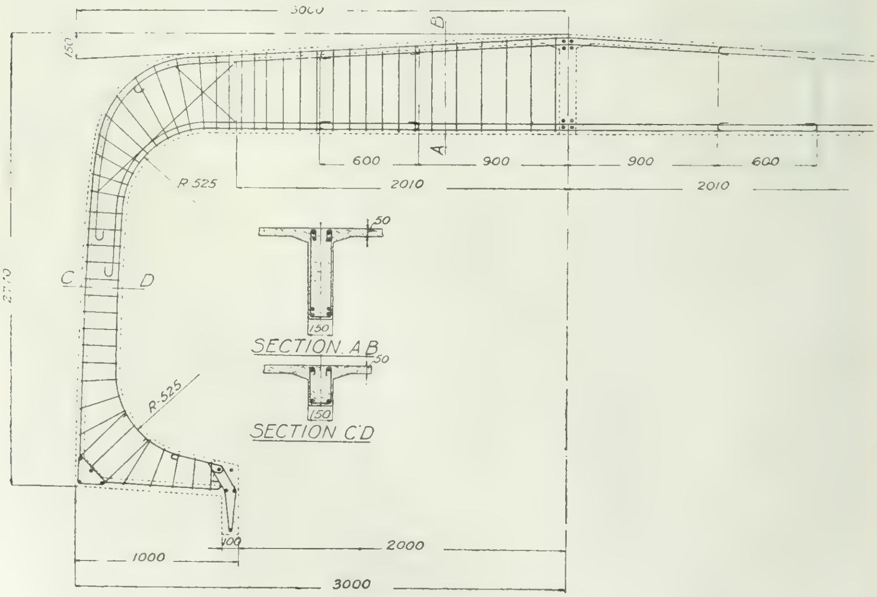


Fig. 9. Reinforcement for Rib 18.

The low cost and rapidity of construction are such as to offer great possibilities to the shipbuilding world. Consequently the Porsgrund Co. is pushing the work vigorously and expects to build larger and ever larger boats, suitable for overseas traffic. The present demand for vesels is such that, to meet them and to cope with anticipated orders, a licence has been granted to a

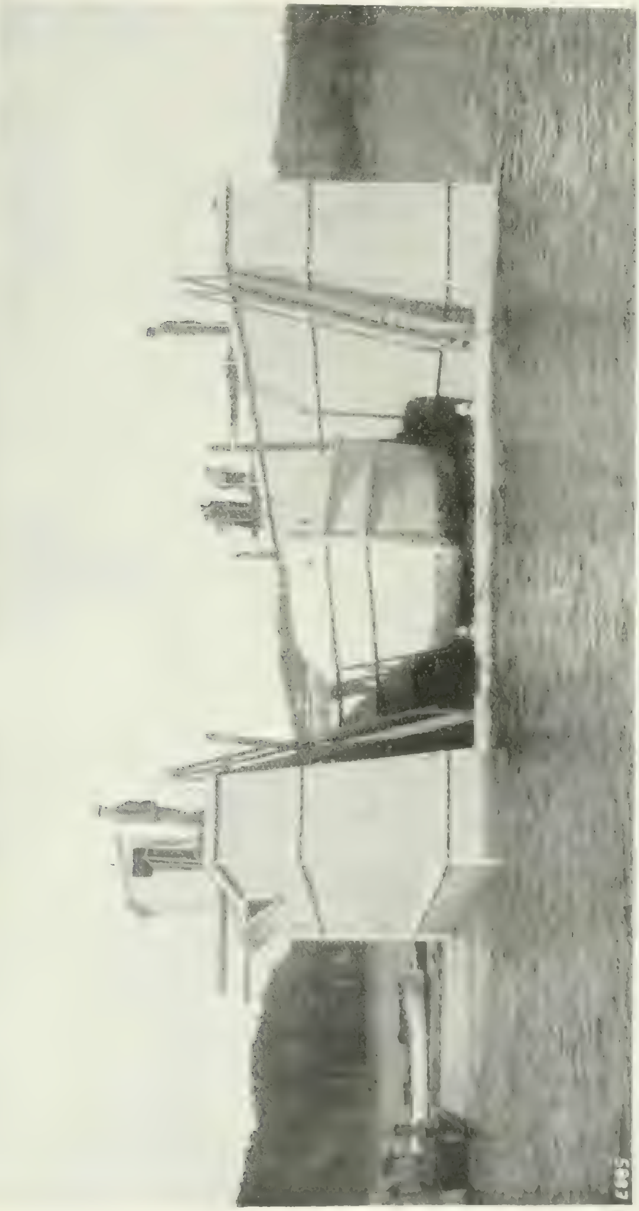


Fig. [illegible]. Floating Dock built of Steel Concrete, with Fougner Steel Concrete Lighter inside.

subsidiary firm—Verstlandsk Betonbaatbyggeri A S, of Ytre Arne, near Bergen.

Concrete vessels are relatively heavier than those built of steel, but the patentees claim for them the advantages of greater durability, more resistance to fire, greater cheapness, and rapidity in the construction of vessels of standard design, and great facility in repairs. There can be no question as to the suitability of concrete barges for relatively quiet waters, and their use in large numbers for this purpose may be anticipated with confidence, especially as the Committee of Lloyd's Register of Shipping has approved the erection and will facilitate the insurance of reinforced concrete vessels up to 500 tons deadweight capacity. So far as their use on the high seas is concerned, much must be left to actual trial. Notwithstanding this fact, there is an enormous demand for reinforced concrete barges at present as a means of increasing tonnage whilst using a minimum of steel, and that in the simplest possible form.

We understand that there is an immediate prospect of reinforced concrete vessels being built in this country, and this will enable us to keep in line with our Allies and other nations in this very important matter.

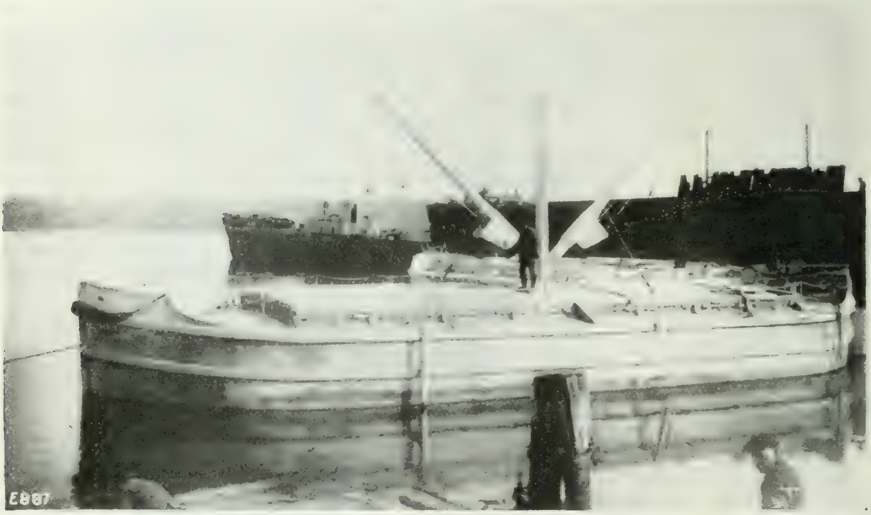
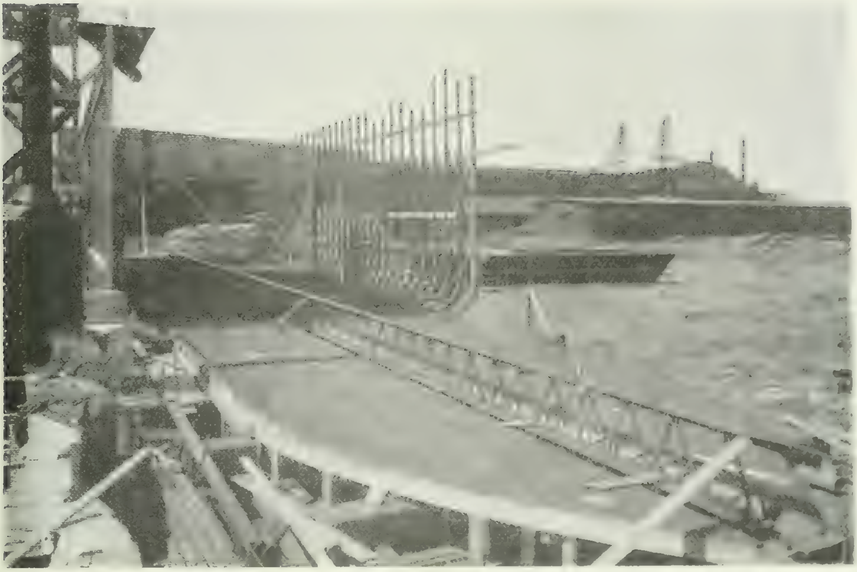


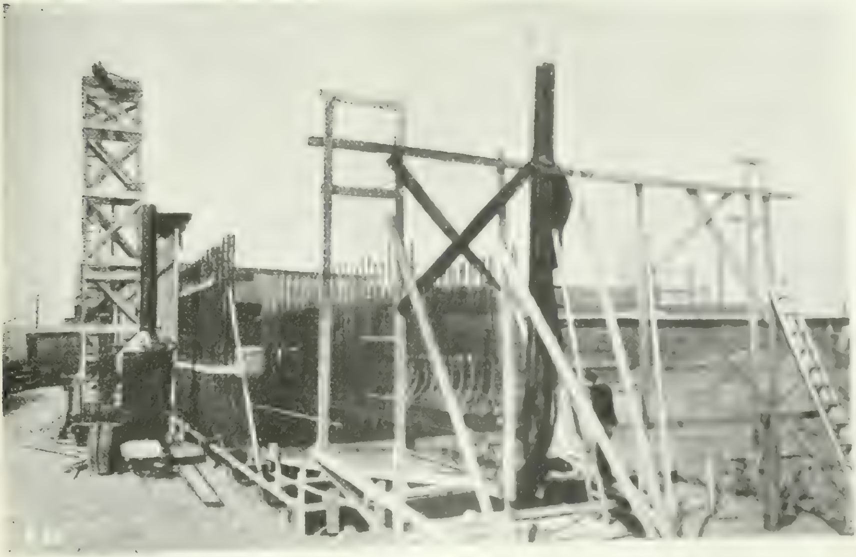
FIG. 11. FOUGNER STEEL-CONCRETE LIGHTER OF 100 TONS D.W. CAPACITY USED BY THE NORWEGIAN NAVY.

MEMORANDUM.

An Example of Rapid Shipbuilding in America.—The accompanying four illustrations show the weekly progress of a concrete ship under construction at Montreal by the Atlas Construction Co. The vessel has a length of 125 ft., a beam of 22 ft., and a depth of 13 ft. She will be of the single-screw type, capable of a speed of about 8 miles an hour. The constructional steel ribs are set 27 in. apart, and the concrete shell is from 3 to 5 in. in thickness.



The Ship on September 7th, 1917.



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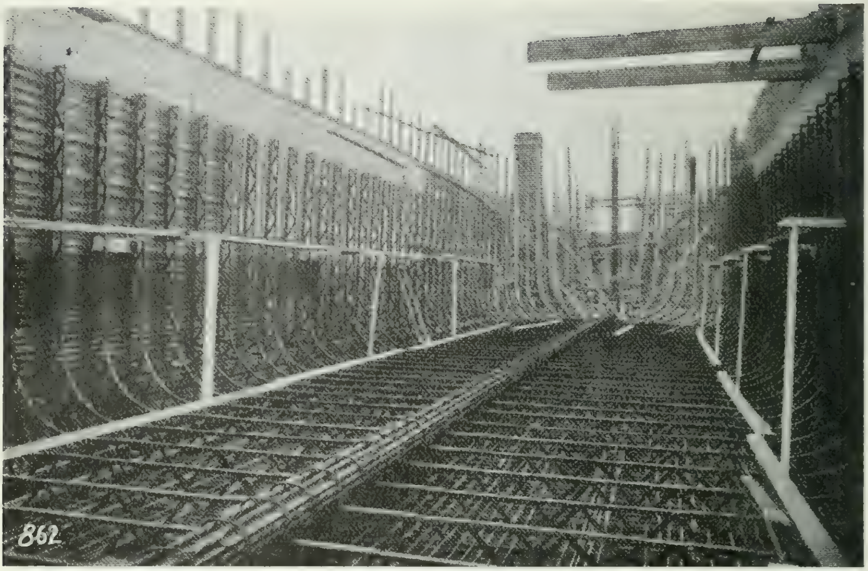

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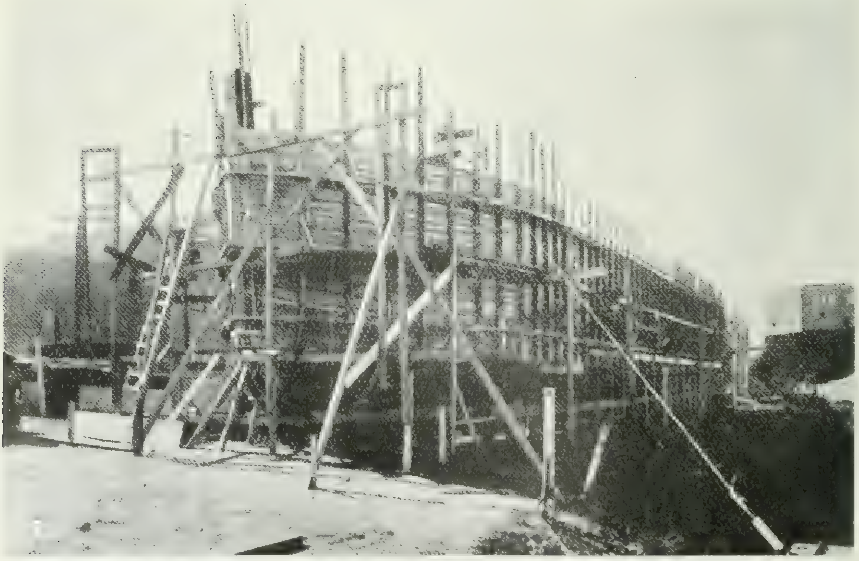

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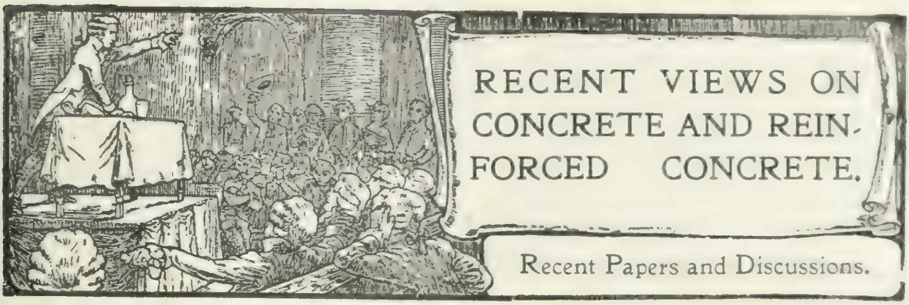

RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE CONCRETE INSTITUTE.

THE CORROSION OF IRON AND STEEL, WITH SPECIAL REFERENCE TO REINFORCED CONCRETE.

By J. NEWTON FRIEND, D.Sc., Ph.D., F.I.C., Carnegie Gold Medallist.

The following is an abstract from an exceedingly interesting paper read before the Concrete Institute in November. In the first part of the paper the author dealt at some length with the early history of iron. A short report of the discussion which followed is also given.—ED.

OWING to the unprecedented importance of iron in its relation to modern civilisation the early history of the metal possesses peculiar fascination for the antiquary. It is safe to assert that the wonderful progress which has marked our path during the last 100 years would not have been possible had not the earth possessed an abundant supply of iron ore. It is iron in some form or other that constitutes the backbone both of our railways and of our mercantile marine. Again, reinforced concrete, in which we are all specially interested, owes what strength and adaptability it possesses almost entirely to its iron frame. I am sufficiently optimistic to believe that a brilliant future is already assured for this material.

HISTORY OF CORROSION.

The tendency for iron to rust upon exposure to air is too pronounced to have escaped the notice of even the most primitive workers of this metal. Pliny, who compiled his famous *Natural History* nearly 2,000 years ago, waxes eloquent on the subject. "Nature," he writes,* "in conformity with her usual benevolence, has limited the power of iron by inflicting upon it the punishment of rust; and has thus displayed her usual foresight in rendering nothing in existence more perishable than the substance which brings the greatest dangers upon perishable mortality."

Although rusting of iron has been observed for thousands of years, it is only comparatively recently that commercial interests have demanded a thorough scientific study of the subject; and as iron becomes more and more the consort of civilisation, so will the need of combating corrosion become proportionately greater.

CONDITIONS ESSENTIAL TO THE CORROSION OF IRON.

Before passing on to consider the means of preventing the corrosion of iron it may be well for us to pass briefly in review a few of the more important facts concerning the cause of rust formation.

1. Water alone is without appreciable action upon iron at ordinary temperatures.

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* Book 34, Chap. 41. Translated by Bostock and Riley, 1857.

2. Water vapour is without visible action upon iron at ordinary temperatures.

3. Dry air or oxygen has no visible action upon iron at ordinary temperatures, but when the temperature is raised to 220° C. iron acquires a pale yellow tint and at higher temperatures becomes straw coloured, purple, and finally blue. These are known as tempering colours and are caused by thin superficial layers of oxide, as is proved by the fact that they are not produced even by prolonged heating in vacuo.* They are obtained even in perfectly dry air, such as that resulting from prolonged exposure to phosphorus pentoxide.† These layers tend to protect the underlying metal from attack and differ from rust in being anhydrous and tenacious. Rust, on the other hand, is usually hydrated, porous, hygroscopic, and friable.

4. A mixture of water vapour and air is without action on iron at ordinary temperatures, provided no liquid water is allowed to condense on the metallic surface.

THE CHEMICAL NATURE OF RUST.

Rust is essentially hydrated ferric oxide, the extent of hydration varying considerably according to circumstances. In colour rust ranges from brown to red, and it usually happens that the red is less hydrated than the brown. Some ferrous oxide is generally present, particularly if the metal has not been completely oxidised away. This oxide has a blackish appearance and may be found in the innermost layers close to the metal.‡ Rust also contains free water in addition to that chemically combined with it, for it is a hygroscopic, porous mass. It also readily absorbs carbon dioxide from the air. These two properties serve to render it an active stimulator of corrosion. The carbon dioxide dissolves in the water to carbonic acid, which attacks a portion of the iron yielding ferrous carbonate. This, in turn, is oxidised by the air to rust.

According to Bauermann, when iron rusts it expands to some ten times its original volume. This may possibly be somewhat of an exaggeration, but the fact remains that very appreciable expansion does take place on rusting, a property that is made use of by the plumber in his rusts joints. This expansion is, to the worker in ferro-concrete, a serious problem. If the metal once begins to rust a cracking of the concrete is inevitable; more air and water enter so that corrosion now proceeds apace, and the structure becomes proportionately weakened.

THE INFLUENCE OF INORGANIC SALTS UPON THE CORROSION OF IRON.

The influence of aqueous solutions of inorganic salts upon the corrosion of iron depends upon a variety of factors such as, for example, the chemical nature of the salt, its concentration and the temperature of the solution.

At ordinary temperatures a very dilute solution of sodium carbonate is considerably more corrosive than tap water. But if the concentration be increased to 0·25 per cent. and above, the metal is entirely protected from rusting. Similarly, a 3 per cent. solution of common salt at about 10° C. is much more corrosive than tap water at the same temperature, but as the temperature rises the relative corrosivity falls, so much so that at 21° C. the solution is appreciably less corrosive than tap water. Since sea water contains some 3 per cent. of sodium chloride it is of interest to inquire into the effect upon its corrosive powers of diluting it with river water, for this occurs in nature at the mouths of many rivers and has to be reckoned with by the engineer.

THE INFLUENCE OF ALKALIES UPON THE CORROSION OF IRON.

For many years it has been known that alkalies, if present in sufficient concentration, will completely inhibit corrosion. The merest traces of caustic soda or potash will suffice to prevent rusting in aqueous solution provided such solution is protected from neutralisation by the carbon dioxide of the air. Should, however, large supples of air gain access, carbonates are produced and these greatly accelerate corrosion unless the concentration of alkali is sufficiently great to yield 0·25 per cent. solution of carbonate, as has already been mentioned. Lime, of course, behaves similarly to caustic soda or potash. Hence in attempting to protect iron permanently with free alkalis, such as lime, it is necessary to consider, not merely the protection afforded by fresh caustic lime, but that which will be afforded when the atmosphere has converted the lime into carbonate.

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* Roberts, *Trans. Inst. Mech. Eng.*, 1881, p. 710.

† Friend, *J. Iron Steel Inst.*, 1909, II., 172.

‡ See Analyses by Moody, *Trans. Chem. Soc.*, 1906, **89**, 726.

An interesting case arises when iron is immersed in alkaline solutions containing inorganic salts. For example, iron will remain bright in a 1 per cent. solution of caustic potash for an indefinite time, but upon addition of potassium chloride corrosion readily takes place. It is possible, however, to increase the alkali to such an extent that corrosion is entirely prevented, no matter how concentrated the solution of chloride. The minimum amount of alkali required rises with the percentage of chloride until saturation of the latter is arrived at.

A curious point about this type of corrosion in alkaline solution is the fact that it invariably takes the form of pitting.* Lumps of rust grow at various points on the surface of the metal, and, when scraped away, leave holes or pits in the same. The rust invariably contains a dark oxide close to the metal, and surrounded by ordinary brown hydrated ferric oxide. Most probably the pitting originates at points where traces of impurity are present. These traces are exceedingly difficult to remove, and are readily found on etching the surfaces of even the purest commercial irons. For example, Kahlbaum's pure electrolytic foil readily pits under these conditions, whereas in ordinary tap water or in aqueous solutions of neutral salts it usually rusts evenly over its entire surface.

If now we replace the potash by lime and the chloride by silicates and sea water we have the condition of things represented by iron in concrete and exposed to the sea, as, for example, in dock piles.

Our subject has thus an important bearing upon the work of the concrete engineer, which we shall now proceed briefly to discuss.

THE PRESERVATION OF IRON IN CONCRETE.

From the foregoing it is evident that the preservation of iron in concrete may be effected in one or more of three ways, namely :—

1. By complete exclusion of air.
2. By complete exclusion of water.
3. By rendering the concrete sufficiently alkaline to place it within the inhibiting area.

If the engineer can make his concrete conform perfectly to any one of these conditions he has achieved his object, for the reinforcing metal will not rust. Unfortunately, in practice, materials cannot be relied upon to yield perfect results and the engineer's best policy is to conform as nearly as is reasonably possible with all three conditions. In this way he may hope so to reduce the tendency to corrode as to render it negligibly small within finite time.

The following considerations suggest themselves as worthy of careful study :

1. None of the concrete materials should be too coarse, otherwise thorough mixing and good contact between the different ingredients will not be as perfect as is desirable.
2. It is essential to press or ram the mixture well into position [illegible] eliminate voids in so far as is possible. It is obvious that voids tend to increase permeability to water and air and are in consequence highly dangerous.
3. A sufficient thickness of concrete should be applied to the metal. If too thin the concrete may not be sufficiently impervious or it may crack mechanically, and thus admit air and water to the metal.
4. Stray electric currents must be avoided. If the metal should become anodic, rusting would take place in consequence of the liberation of oxygen, and this leading to cracking, would rapidly destroy the cement.†
5. Substances likely to contain acids or acid-producing bodies should be avoided. Coke breeze and slags are cases in point, as they frequently contain injurious sulphur compounds.

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* Friend, *Science Progress*, 1913, 5, 202.

† See Nicholas, [illegible]

6. The concrete may be advantageously coated with some waterproofing material to render it still more impervious, provided such proofing is entirely free from acid or acid-producing substances.

It will be observed that certain of the above suggestions harmonise very well with those arrived at on entirely different grounds and published in the Report of the Science Standing Committee and read at the general meeting of the Institute on March 9th, 1911.

CONCLUSION.

Had time permitted it was my hope to deal with other important questions, such as the best metals to use in reinforcing concrete, the treatment of the metallic surface prior to encasing with concrete, and so on. These problems, however, must be relegated to some future occasion.

DISCUSSION.

The President said the paper to which they had just listened was quite unique in their annals; they had never had anything quite like it before, and while it was a new treatment of the subject as far as their Society was concerned, it certainly would not fail to be of enormous practical utiliy to them, and had given them much food for thought.

Mr. Searles Wood, in proposing a vote of thanks to Dr. Newton Friend, said that the subject of the paper was one which had always had a very great interest for him, and it was one which he had tried to follow in various text books, but he had never had it put before him so clearly.

Mr. E. Flander Etchells remarked that there were two theories—the electrolytic and the chemical. The author appeared to adhere more closely to the chemical theory. He would not attempt to decide between the two; there was much to be said on both sides. There were three or four instances in which rust had specially come under his notice. One of them was the case of a railway bridge in which the web plates had rusted through right from one main angle to the other, and from one web stiffening to the other, and yet that bridge was carrying its load. Presumably it was carrying its load because the stress, in the first instance, had been rather low, and the main angles had been sufficient to take up any bending moment which came on after the web had corroded away. That had only shown him the desirability of leaving some margin for strain in the original design, rather than following very close methods of design and working to the last place in decimals in settling their web thicknesses by some of the finest theories imaginable.

Another case was a pier in which he had to ascertain the size of some lattice bars with a view to replace those girders. He found he could quite easily break off the lattice bars in his hand and carry them away with him, although some of them were 3 in. by ½ in. originally They seemed to have been converted into rust through and through. The material would not stand the specified 28 and 33 tons per sq. in.

Another case was a railway girder, which, at any part of the middle of the flange, they could pick off layers of rust ⅜ in. thick, so that the flange was denuded by that amount. That again showed the desirability of making some provision in the original design for the rust. He suggested that that provision should not turn on the question of stress alone.

Another instance was where some bars which were exposed to the air were always rusting. It was decided to have them cleaned and painted. They had been rubbed over with emery paper, cleaned and scraped. To get all dirt and grease off them they were washed with a solution of soda, and that seemed efficacious as any paint, and as the bars were not exposed to the rain they were remaining white and bright to this day, just with a silver layer over them. That was produced by an alkaline solution and nothing else. If they were painted the rust would start again.

A further instance was that of a web which was designed for 28 to 32 tons per sq. in. It was designed to take compressive stresses; it was simply like so much paper now. He saw the calculations for that girder, and the stresses were calculated to 7·26 per sq. in.

Mr. C. H. W. Biggs held, and had held for a good many years, that pitting was absolutely due to electric action. When pitting was going on they had the whole of the necessary constituents of an electric battery. This had been discussed in the electrical world over and over again, and the conclusion arrived at was the one he had stated. There was no possible means of getting rid of electric action in any metallic road or any metallic piece of work. There were two kinds of electric action going on, the conductive and the negative. If they had a thunderstorm they had a surging of electricity through any work they had and they could not get rid of it. Whether that assisted in the rust or not he did not know. He did not think it did to any very great extent, but that was totally different from the electric action that went on when they had a current of electricity escaping from an electric main. How were they to stop rusting? They had heard of a great many things to be painted on iron, but none of them seemed perfectly efficacious. One had just been put on the market which he was told had a property which ordinary paint had not, and that the ordinary preservative had not, in that it was very much after the fashion of a paint which was put on as a paint, but it was elastic, and, therefore, changes of temperature did not cause any action which would prevent it covering the metal. They wanted to stop this terrific loss which was going on year by year, and it was terrific. They had had 80,000,000 tons of ore turned into iron during the course of the year, and they lost 5 per cent. of that.

Mr. Hoare pointed out that there were on the market a good many waterproofing compounds which might be mixed with concrete. He wondered whether any of these might contain some acid which, later on, would develop a tendency to affect the iron; while keeping the water out of the concrete it might have some anterior effect upon the iron.

Mr. Ewart S. Andrews, B.Sc., joined issue with Mr. Etchells on his reading of the lessons to be obtained from the paper and the effects upon structural design. It seemed to him that if they were going to fail to design their steel work economically just because of some unknown contingency as to rusting, something which they could not measure, they were merely putting their heads into the sand. They were failing to obtain the real information which they wanted, and that, he thought, was a great danger. If engineers were to be satisfied with allowing for rust by knocking down their working stresses, which they knew they ought to be working to, one half, he thought they were going to ruin trade. They ought to obtain from the chemists or the metallurgists all the aid they ought to have. He hoped engineers would be brought to realise the great value which the chemist and the metallurgist could be to them, and greater collaboration between the two might remove the difficulties which had stood in the way in the past. They did not want to allow for rust in some indefinite haphazard sort of way. If by working stresses they were to allow for rust, they must set some time limit on the extent of their structure, and that seemed to him to knock a hole in the argument. They must not attempt to alter their design; they must attempt to prevent rusting.

Mr. W. J. H. Leverton suggested that the author of the paper should give examples of steel which had decayed in reinforced concrete work.

Mr. Lucien Seraillier asked for further information of what was foreshadowed at the close of the paper, where Dr. Newton Friend had spoken of the best metals to use in reinforced concrete. He presumed the author of the paper meant the different classes of steel and their relative corrosiveness. It would be also interesting to hear what he had to say regarding the treatment of metallic substances.

The President also expressed the hope that Dr. Newton Friend would be able to tell them something about the point raised by Mr. Seraillier, and particularly whether there was any probability of rustless steel coming into general commercial use. He had some knives at home that he had had now for about two years. They had never been cleaned on a knife-board or with any sort of emery paper, and they were bright as the day they were purchased; they had been washed in the usual way. They were sold as rustless steel, and he believed it was a steel with cronium in it. It would be a most admirable and useful thing if they could get a steel that they could absolutely say would not rust under any circumstances. The practical conclusions in the paper were exceedingly interesting. He would only notice the last one, number 6, that the concrete might be advantageously coated with some waterproofing material to render it still more impervious under certain conditions. That seemed to him the most important thing for the engineer who had to use reinforced concrete in sea water. The most trying conditions under which reinforced concrete was used was when it was used in or, rather, above sea water. It was there that corrosion was likely to take place, and they would know from reports which had been published that at Southampton they had had some such experience. The most curious thing was that the oldest structure of all in Southampton had not suffered at all, while some that had been built since had suffered quite remarkably from the sea water apparently getting through the concrete envelope to the steel, rusting it and bursting off the concrete envelope. At one time he had an idea that this might be due to stray electric currents. He hardly thought so now, but that led him to consider the advisability of waterproofing the concrete, because he had noticed that American experiments on electrolytic action on iron or steel buried in concrete had shown that the liquid surrounding reinforced concrete appeared to be driven through the concrete to the steel. A coating such as the author recommended would be useful as a protection, not only against the ordinary atmospheric corrosion, but corrosion aggravated by electrolytic action.

THE LECTURER'S REPLY.

Dr. Newton Friend, in replying on the discussion on the question of electric action and corrosion, asked what was electric action. It was simply pushing the question one stage further back without offering any explanation. Simply to say that a difference of potential existed between the metal and the impurity was not an explanation. He quite agreed with Mr. Biggs as to the difference in potential causing corrosion, but he confessed he failed to see that it offered any adequate explanation. The point was, could they get behind that explanation and find out in what the difference of potential really consisted? If they could do that many of the difficulties surrounding them in preventing iron to suffer by this action would be overcome immediately. They might leave the subject of steel decaying in concrete till some future occasion. The cases which had come under his own personal observation of the decay of steel in concrete could usually, if not always, be ascribed to some point in which the 6th suggestion at the end of the paper had not been adequately followed. He did not suppose it was possible to make a perfect reinforced concrete because they were up against the limitations of material. At the same time, if it were possible to perfectly follow any one of these six points, he very much doubted whether steel would ever corrode in concrete. In determining the best kind of metal for reinforcing the concrete it was necessary to know the exact conditions under which the concrete would be exposed in nature. For big piles a different kind of reinforcing metal was required than for buildings which would never be exposed to liquid sea water.

MEMORANDUM.

Bushing for Conduit Risers in Reinforced Concrete Buildings.—If provision has not been made during the design and construction of a reinforced concrete building for installing conduit risers, much trouble and expense are involved in their subsequent installation. Frequently one finds in concrete buildings that the risers have not been installed until after the concrete work was completed, which means that it was necessary to drill through solid floors with the probable chance of striking metal reinforcement, which was likely to cause the hole to be enlarged, or to require another hole to be drilled, either of which throws the riser from the true vertical. Of course, this is very slow and expensive work, and therefore everything should be done to secure a proper location of the risers and provision so that they may be installed easily.

Where the size and location of the risers have been shown on the plans the best method of avoiding drilling of floors is to provide a set of bushings through the forms before the concrete is poured. For this purpose a quantity of metal downspout, preferably smooth pipe in place of corrugated, should be used. The inside diameter of this spout should be slightly larger than the outside diameter of the conduit. Several different sizes may be needed. Slot the end of the spout with a pair of ordinary tin snips to the depth of one inch or more. The width of the slots can vary. Then bend the metal outward at right angles between the slots, so as to form a sort of broken flange. Cut the spout about one inch longer than the thickness of the floor. Now locate the position of the conduit riser and mark it on the concrete form. Then fasten the spout securely to the form where the conduit is to be installed, nailing through the flange to secure the inverted spout to the form. The top of the spout should then reach about one inch above the finished floor. The spout is then filled with sand. The reinforcement and concrete are then put in place without chance of disturbing the spout, which when the form is removed and sand allowed to run out leaves a clear hole through which the riser is easily run.—*Electrical Engineering*, New York.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

The Faraday Society.—A general discussion on "The Setting of Cements and Plasters" will be held on Monday, January 14th, 1918, at 5.30-7.0 and 8.30-10.30, by the Faraday Society, in the rooms of the Royal Society of Arts, John Street, Adelphi, London, W.C.2. The following is the preliminary programme:—Dr. C. H. Desch (Glasgow) will open the discussion with a paper on "The Mechanism of the Setting Process in Plaster and Cement." Professor H. Le Chatelier will send in a communication on "Crystalloids *v.* Colloids in the Theory of Cements." Mr. A. A. Klein (Worcester, U.S.A.) will send in a paper on "The Constitution and Hydration of Portland Cement." Mr. George A. Rankin (Creighton, U.S.A.) will send in a paper on "The Setting and Hardening of Portland Cement." Mr. Bertram Blount will read a paper on "The Setting of Cement in its Relation to Engineering Structures." Mr. John Rhodin will read a paper on "Note on the Colloidat Theory of Setting." Mr E. H. Lewis and Monsieur E. Deny (Wishaw) will read a paper on "The Effect of the Addition of Suitable Slag on the Setting Properties of Portland Cement." Mr. W. J. Dibdin will read a paper on "Ancient and Modern Mortars." Mons. R. Feret (Boulogne-sur-Mer), Mr. A. Binns, Dr. E. B. Butler, Mr. W. J. Cooper (Penarth), Mr. Alex. L. Feild (Pittsburgh, U.S.A.), Dr. T. Martin Lowry, F.R.S., and Dr. J. W. Mellor will also contribute to the discussion.

Members of the Concrete Institute are being invited to attend the meeting. Others interested in the discussion, or desirous of being present, should apply to the Secretary, Faraday Society, 82, Victoria Street, S.W.1.

Housing of the Working Classes—Cottage Competitions.—The time for sending in designs under this competition, of which we printed particulars in our December issue (p. 681), has been extended to January 31st. The following particulars have been issued in response to questions by competitors:—

SUPPLEMENTARY PARTICULARS IN RESPONSE TO QUESTIONS BY COMPETITORS.

1. The floor areas given apply to all classes, and are to be net area clear of all projections. The floor of living-room should have an area of not less than 180 ft.

2. The heights of storeys may be from 7 ft. 6 in. to 8 ft. in the clear. Bedrooms may be partly in the roofs, but not less than two-thirds of the ceilings must be of the maximum height; and the vertical walls must not be less than 5 ft. high.

3. The bath should be fixed and not of the tip-up type. It is not essential that a separate bathroom should be provided. The w.c. should not be placed in the bathroom or entered from the scullery.

4. No drainage need be shown, and it may be assumed that access to the houses is from both front and back, and no gardens or plans of site need be shown.

5. No alternative plans will be allowed.

6. All drawings are to be drawn with the long dimension of the paper horizontal, and each class is to be clearly marked A, B, C, or D, as the case may be.

7. Each class is to be shown on a *separate* sheet, and the classes may not be intermixed.

8. The drawings are not to be mounted on strainers, and are to be in black ink, with a black wash over the window openings. No perspectives are to be sent.

9. The fact of a design being premiated will not prevent the author from making use of it in his practice if he so desires.

10. The two elevations asked for may be such as the competitor thinks will best illustrate his design.

11. The assessors in each competition will have the option of recommending designs of special merit for further premiums (or honourable mention) in addition to those stated in the conditions.

12. Each of the Classes A, B, and C is to be designed as a block of five or six houses, of which three are to be drawn in detail, the others in outline only. Of the three which are to be fully drawn, one is to be an end or semi-detached house, another a terrace house between party-walls and lighted front and back only, with frontage of 18 ft. from centre to centre of party-walls, and the third to be a house one room deep only, with long frontage at the discretion of competitor. The grouping or composition of the block may be arranged in any way the competitor desires. A section of one house in each block, if sufficiently explanatory, is all that is required.

13. It may be assumed that water supply is available.

14. A Committee of Assessors will be appointed by the Architectural Societies in each area.

The following points are given as desirable, but are not to be regarded as essential:—

Staircase should have direct ventilation.

Coals should be accessible under cover, and accommodation should be provided for at least one ton.

Scullery should be large enough to serve as a relief to living-room, but not large enough to take centre table.

Reinforced Concrete Poles for Transmission Cables.— In a recent issue of the *Iron and Coal Trades' Review* there appeared a short description by Mr. A. V. Chitty of some reinforced concrete poles erected at a colliery. We reproduce the description and illustration, as they are of considerable interest at the present time, when timber is scarce and expensive:—

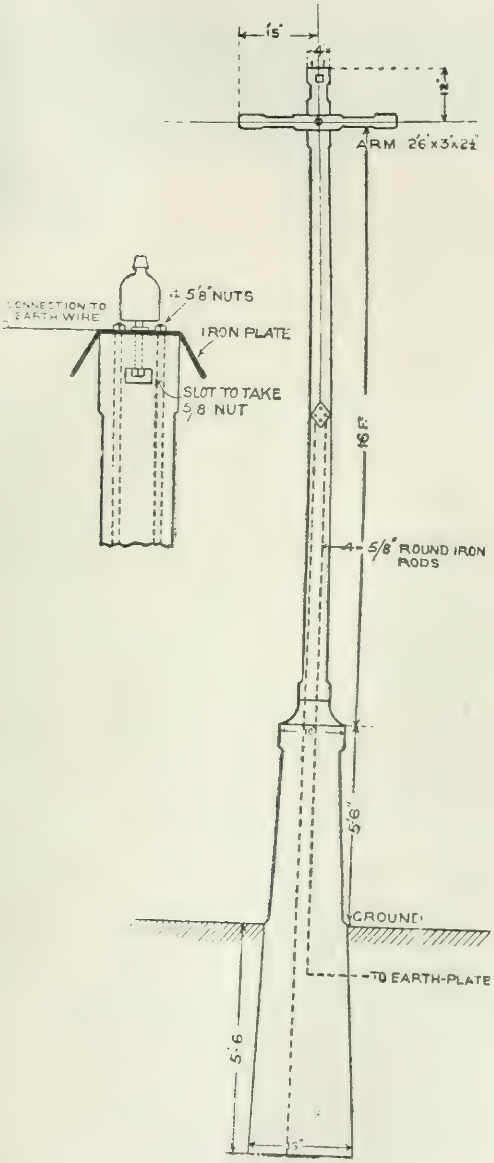
The colliery where these poles to be described have been made and erected has undergone a complete change, for no electricity of any kind had been in use before. The new houses for engines, pumps, boilers, etc., have all been built with reinforced concrete, so that when the poles came to be made everything was ready for the purpose.

As the poles were not required for a few months, one mould served to make them all. The mould was made ready; then as opportunity occurred the concrete was put in, and when finished left to set for about fourteen days, according to the weather. A little water was thrown over the concrete occasionally to assist the hardening, and when set sufficiently the box was taken off and made ready for another mould. At this stage the poles were quite "green" and not safe for handling.

The concrete mixer was kept going principally to make concrete for the buildings, etc., but there are periods during work of this description when delays occur, especially at the present time. When the mixer was not supplying concrete for buildings the concrete was used for moulding a pole.

The illustration gives the dimensions of the pole. Reinforcing rods run the full length, and iron wire was fastened in between the rods to give a better binding. One rod was bent about 4 ft. from the bottom of the base and brought out at the side. An earth-plate was attached to this rod after the pole was erected. At the top the rods project for sufficient distance to take an iron plate about 3-16 in. thick and a $\frac{5}{8}$-in. nut. A hole was left in the top to take the top insulator spindle, and a slot in one side to enable the nut to be secured. A rod was fastened to one of the nuts to carry an overhead earth-wire. About a foot from the top a slot was left to take the cross-arm and a bolt hole for securing same.

The arms were 2 ft. 6 in. long by 3 in. square, chamfered at the edges, and secured to the pole by a $\frac{5}{8}$-in. bolt. Three inches from each end of the cross-arms are the insulators. The shortest distance between the wires, providing they are all at an equal tension, is about 15 in., which for a 440-volt 3-phase transmission is ample.



Reinforced Concrete Poles for Transmission Cables.

The weight of a 28-ft. pole is about 2 tons 7 cwt. Each pole was placed on rollers and moved to its place of erection, care being taken to see that the rollers were fairly equidistant to obviate risk of cracking the concrete, which did happen in one case. The best method is to move the pole on planks strapped to it.

The ground where these poles were set up was good solid clay with about 8 in. of soil at the top. The hole was stepped down to about 5 ft., so as to leave a solid wall at the back. The pole was then placed over the stepped side of the hole and set into position by means of a derrick.

A board was placed against the bulk wall to prevent it burying itself in the ground and breaking the earth away while being lifted. No stay wires were used, as they were not considered necessary in a sheltered colliery yard; also the length of span is only about 40 yards. For a transmission line, say from one colliery to another, through open country, wind stays might be necessary.

One of the reinforcing rods of each pole has an earth-plate attached at the base, and the poles are connected together by an overhead earth-wire which terminates at a steel tower. The wire is taken down the tower and connected to two earth-plates about 20 ft. apart. These plates serve as a central earth for all the surface motors and the underground circuits. It is not necessary for each pole to have an earth-plate, but they were convenient for connecting the motors to. In the case of a long line with a number of poles an earth-plate at every fifth pole would suffice.

The approximate cost of the pole is about £3 10s., including reinforcement and the mould. A wooden creosoted pole would cost at the present time about 2s. a foot. The life of a wooden pole would be, say, 15 to 20 years, whereas a reinforced concrete pole should last as long as the colliery. For general appearance and strength concrete is best.

Concrete Roads.— In the course of the discussion on a paper read by Mr. T. Adams, town planning adviser to the Canadian Commission of Conservancy, on Town Planning in Canada, before the Town Planning Institute, questions were raised as to the development of roads in the Dominion. Mr. Adams explained that the tendency to-day is to construct an asphalte pavement on an 8-in. foundation of concrete, with very solid concrete walls on each side, going down 3 ft., so as to

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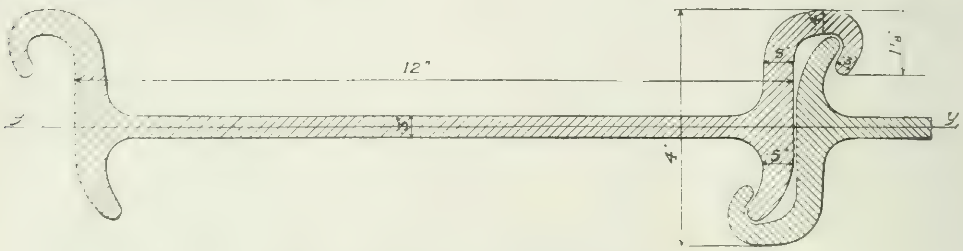

— Weight of Section = 27 lbs per lineal foot —
— Weight of Piling = 27 lbs per super foot —
— Moment of Inertia about y-y – 5·98 ins⁴ —
— Patent No 12063/12 —

Section of 27 lb Simplex Piling

SIMPLEX STEEL SHEET PILING

Width.		Weight.
No. 1	8 in.	22 lbs. per super foot.
No. 2	12 in.	26·5 lbs. " "

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prevent the frost getting underneath the pavement. They were making the pavement so durable that it would stand for years with little cost for maintenance. It meant that concrete roads were becoming very much the rule, because such roads properly constructed were, so far as he could see, working out very well indeed, and they had the advantage of costing very little for upkeep.

Work in Nigeria.—In the Colonial report dealing with Nigeria, just issued, it is stated that progress in regard to harbour works has been slow. The Apepa Wharf extension was practically completed, and the Customs Wharf extension, 100 ft. up-stream, in reinforced concrete, was commenced. Work was also started on the piles for the 400-ft. extension down-stream. The total length on completion will be 1,185 ft.

Works at Shanghai.—In his report dealing with the extensions to the Shanghai Municipal Generating Station, Mr. Aldridge, the electrical engineer, states that an interesting feature of the extension will be the new 22,000-volt combined switch-gear and transformer house, which is being constructed throughout of reinforced concrete. ——The directors of the Shanghai Electric Construction Co., in their annual report, state that land has been secured for additional offices, and a building of steel and reinforced concrete is to be erected.

Yolo Basin Concrete Trestle.—The concrete trestle completed last year by the California State Highway Commission is believed to be the biggest work of its kind in the world. It is nearly three miles long, and traverses the Yolo basin, a marshy track which is flooded frequently. There is a clear width of drive way of 21 ft. The average height of the trestle is 20 ft. It consists of reinforced beam and slab construction in 20-ft. spans, resting on reinforced concrete piles 32 to 50 ft. long. The material cost 148,000 dollars, and the construction 246,000 dollars.

Reinforced Concrete Piers in Japan.—A Bill to construct two large reinforced concrete piers in front of the so-called trade zone, which extends from the big pier at Chikko, in Osaka, to the mouth of the Shirinashi-gawa, has been submitted to the Osaka Municipal Assembly. The *Osaka Mainichi* states that the newly-designed piers are to be something like islands, quite apart from the shore. Each is to be 200 ken long, while one will have a width of 55 ken and the other a width of 77 ken. Enough quay space is to be provided for two 6,000-ton steamers to be moored alongside at one time. The piers are to be connected with the shore by swinging bridges. The sea near the piers is to be dredged to a depth of between 29 ft. and 33 ft. The total cost of this new work is estimated to be about 6,000,000 yen. When these structures are completed it will be possible to handle 900,000 tons of merchandise at Chikko. In addition, a Bill to extend the railway to Chikko has been presented. This provides for an outlay of 2,200,000 yen. The work is to be completed in six years, and it is hoped to commence work next year. (1 ken = 5·9 ft.; 1 yen = 2s. 0½d.).—*The London and China Telegraph.*

Reinforced Concrete at the Tursdale Colliery, Durham.—In a recent issue of the *Iron and Coal Trades Review* an interesting article appeared describing the remodelling of the surface plant of the above colliery. The new structures include a reinforced concrete heapstead and headframe and a number of other reinforced concrete buildings, which are of more than usual interest, being on the panel or unit system of construction.

The columns have been constructed horizontally on the ground and lifted up into position when completed, provision being made to take the window-sills and heads, which were also moulded on the ground. Concrete slabs or panels, each 9 ft. by 6 ft., were then built up in pairs between the columns, which, with the cavity, form a 12-in. wall to clothe the building.

Apart from the fact that the unit system of construction is less costly than the usual form of reinforced concrete building construction, it enables the work to be very largely standardised, whilst it affords facilities for extension which are wholly impossible when the building is cast *in situ.*

The lamp cabin is provided with reinforced concrete benches, the reinforcement being expanded metal. The ends of the building are partitioned off for the repair and tinsmiths shop and the oil stores respectively.

The boiler stokehole is entirely under cover. The boilers will be served by an overhead conveyor feeding a series of reinforced concrete bunkers and serving on its return journey for the removal of ashes. The whole of the pipework supports, etc., are reinforced concrete, as are also the poles for carrying the electric wires. These poles are 22 ft. high, 15 in. square at the butt, and from above the butt 12 in. square, tapering to 4 in. square at the top; in these supports one of the reinforcing rods is taken to earth. The company are also manufacturing reinforced concrete pit-props for their ironstone mines, in lengths from 8 ft. 3 in., rising by 3 in. to 9 ft. 9 in. They are octagonal, 4 in. in diameter. The concrete is made of $1\frac{3}{4}$ slag, $1\frac{1}{4}$ sand, and 1 cement, the reinforcement being four $\frac{1}{4}$-in. rods with lateral reinforcement of 3-16-in. wire placed at 6-in. centres. The weight of a 9-ft. prop so made, after weathering three weeks, is 11 stones, as compared with 10 stones 3 lbs. the weight of a timber prop of the same length and 6 in. in diameter.

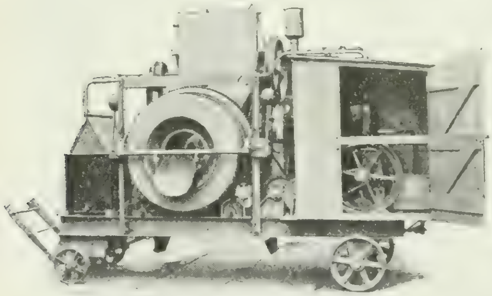
PROPOSED WORKS.

Havre.—A Bill is to be presented to the French Parliament having for its object the enlargement of the port of Havre. The Bill provides for new quays, the construction of two moles on the south side for ships to lie alongside of, and the construction of four dry docks.

Cape Town.—The citizens have given sanction for the raising of £268,000 for new waterworks. The proposed work includes the provision of a new reservoir of 200,000,000 gallons capacity in the Silvermyn Valley, in the Muizenberg Mountains, by the construction of a concrete dam.

Blackpool.—All opposition has been withdrawn to the Corporation Improvement Bill, which provides, amongst other things, for coast defence works at Bispham.

Canada.—The Imperial Trade correspondent at Toronto has furnished to the Department of Commercial Intelligence a copy of the general specifications for concrete highway bridges in Ontario, and also a copy of a report on the construction of highway bridges in that province. British firms interested can consult the publications at the Department of Commercial Intelligence, 73, Basinghall Street, E.C.



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(*See page* 70.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIII. No. 2. LONDON, FEBRUARY, 1918.

EDITORIAL NOTES.

THE METRIC SYSTEM.

A VERY interesting paper was read before the Concrete Institute on January 24th by Mr. E. A. W. Phillips, entitled "British Trade and the Metric System."

We have always considered the question of the adoption of the metric system in this country as a very important one, more particularly to engineers who are called upon to make elaborate calculations, involving considerable time and care; and any method which will tend to reduce this labour must be of benefit to the general community.

The points put forward by the author of the paper above mentioned are particularly interesting, especially from the historical point of view; but we cannot see that his suggestions are sufficient to meet the needs of the future. It is no doubt very satisfactory to know that there is a reason for the system of weights and measures used in this country, and the existence of the tripod in British weights and measures has certainly been proved; but how is this going to help the industry of the country, even if a few alterations are made to remove some of the objections of our present system?

The statement was made that the difference between the French and British metres represents just the unbridgeable gulf between capital and labour in this country to-day, as the British metre, which is equal to the Belgic yard, is 39·60 in., and the French metre is 39·37 in. With this we do not agree, as, while it is quite true that 39·37 cannot be stretched to 39·60, this does not prevent us from adopting a common metric system all over the world, which can be based on the system which is likely to prove of the greatest convenience in the future to all parties. It is now generally accepted by all those engaged in calculations that the use of decimals is far preferable to the use of vulgar fractions, and the reason for this preference is because the calculations can be carried out with greater speed and accuracy, and such a reason is unanswerable.

Now Mr. Phillips, in making a comparison of the French and Britisn systems, appears to be somewhat disturbed at the idea of a possible victory of the decimal system over the vulgar fraction system, because the latter is British and is more ancient. He also states that if the British system is victorious, the decimalists would still be free to employ decimals and no one would be injured. This appears to be rather futile argument, because, in the first instance, although we naturally uphold Britain and British traditions, it is surely not a good policy to put this forward as a reason for stifling progression, and it is dangerous to let sentiment influence us in such matters; and, in the second instance, the British system of weights and measures does not lend itself readily to the use of decimals, and unnecessary labour is involved in the conversion from fractions, and it should be conclusive proof of the great preference for working in decimals that the conversion is so generally made. As an example of the extensive adoption of the decimal system and the advantages which follow the use thereof, let us consider for a moment the slide rule, which is an instrument used by all engineers, and imagine how much time would be lost if its use were discontinued, while a complete adoption of the metric system would make this instrument even more valuable. If vulgar fractions are adopted for calculations, then the slide rule becomes useless, and such a condition will not find favour among engineers. The arguments are, therefore, all in favour of a decimal system as compared with a vulgar fraction one, and the next point to consider is that of the system to be adopted. The French metric system is the essence of simplicity, and might easily be used as the international standard, not only for science but for all purposes, and it possesses the merit of having been in use for a considerable time, and thus it is well known, even in those countries where it is not universally adopted at the present time.

POINTS FOR CONSIDERATION.

Some definite points were put before the meeting by the author of the paper, and we feel that some comment on these is necessary. The two first points dealt with the possibility of restricting the use of the metric system as an international standard for pure science, while the British decimal system would become the international standard for trade, commerce, and engineering. This appears to us as a compromise which would lead to considerable confusion and inconvenience, and no justification can be put forward for the adoption of two systems, as the whole point to be kept in view in the possible alteration of our present system is that of using one standard for all purposes, which standard should be simple, convenient, and likely to be used throughout the world.

The third point put forward dealt with the question of the British system being accorded respectful treatment by other nations, and being legally used as desired in any foreign country, even a metric country, by arrangement between contracting parties. Mr. Phillips puts forward the plea that this would only be bare reciprocity in return for the legal recognition of the metric system in the British Empire, and if there is any real desire for such a condition of affairs there is no reason why it should not be permitted; but this seems hardly necessary, and the legal recognition of the metric system is, we believe, due to the general feeling that this system is an important one, which deserves respectful treatment on its own merits.

The last point is one which is of general interest outside the engineering profession, as it refers to a standard coin, to be minted and used in every nation, even if it is not internationally current. The tendency of the present age is toward a more general combination of the nations, and our isolation is bound to become a thing of the past, and while this combination is being achieved it would greatly facilitate international intercourse and trade if universal standards could be adopted in weights, measures, and currency, and every effort should be made to forward this ideal. By the adoption of the metric system in this country a large step in the right direction would be made, and, in addition, real benefit would be conferred on the engineering and other industries.

THE CHEMISTRY OF CEMENT.

THE recent discussion before the Faraday Society of the setting of cements is almost the first recognition on the part of a technical society in this country of the wide field for scientific investigation that still lies open in connection with the chemistry and physics of calcareous cements. As far as the manufacture of cements, and especially of the most important member of the class, Portland cement, is concerned, the British industry has well maintained the leading position which was historically its due, and the quality of the product has reached a high and uniform level. Nevertheless, it would be a mistake to assume that finality has been reached, either in methods of manufacture or in quality of product, and it would benefit both manufacturers and users if full advantage were taken of the investigations of chemists into the constitution of cements and the reactions involved in their setting and hardening. We are still insufficiently informed as to the changes which take place in mortar and concrete under varying conditions of hardening, and in presence of solutions or substances which may exert a disintegrating effect. Much empirical knowledge on these and similar points has been accumulated by engineers, architects and contractors, as well as by manufacturers, but the industry would gain immeasurably by the improvement of the scientific basis on which it rests. Such has been the uniform experience of other industries, notably that of steel, which have utilised to the fullest degree the results of scientific research.

For our knowledge of the chemical constitution of Portland cements we are mainly indebted to France and to the United States, this country having contributed very little in recent years. The constitution of the clinker has been established by the researches of the Geophysical Laboratory in Washington, and the results, complex though they seem to be when expressed in chemical language, are capable of a fairly simple interpretation. The explanation of the setting process was given in its main outlines thirty years ago by Professor Le Chatelier, and it was of great interest in the discussion to receive a characteristically vigorous paper from this veteran worker, defending his views against a more modern explanation, based on the chemistry of colloidal substances. Several speakers showed that the difference between the two schools was largely verbal, and that it was possible to reconcile them without unduly straining the meaning of terms. The question whether the products of hydration of cement are to be regarded as crystalline or colloidal may appear at first sight to be purely academic, but upon a proper understanding of such questions depends the successful prosecution of further research in this field.

The discussion was of special interest to the pure chemist, but it was shared in by practical experts on the technical side, as well as by engineers. Mr. Caroe referred to the destructive action of cement on certain building stones, a matter which is still imperfectly understood. The same speaker mentioned the influence of clay particles on the strength of cement as another subject which demands further investigation, the data at present available being contradictory. Our methods of testing also call for improvement; thus the setting time is determined for neat cement, whereas cement is scarcely ever used neat, and no definite relation exists between the setting times with and without the addition of sand and aggregate.

A more controversial point was touched upon in reference to the advisability of adding pozzolanic substances to cement, the material chiefly considered being blast-furnace slag. Considerable difference of opinion exists on this point, and the paper presented on the subject, written from one point of view, was eminently suitable to initiate a discussion.

The last two years have seen a remarkable increase in the attention devoted by British manufacturers and leaders of industry to scientific research. The Advisory Council is performing a most useful function in putting forward suggestions and in assisting industries to organise themselves for the undertaking of research on a co-operative basis. The fruits of such activity are already being realised, and as the industrial world becomes better acquainted with the efforts which have been made in other countries, especially in the United States and in Germany, we may expect the movement to spread rapidly and effectively. The contest for markets will be a severe one, and one lesson which has been most powerfully enforced by the war is that of the intimate connection between the success of an industry and the readiness of its leaders to keep abreast of the scientific knowledge of the time, and themselves to aid, by organisation, subsidy, and encouragement, the advancement of that knowledge in their own country.

CONCRETE SIMPLIFIED.

In the current issue we are publishing the first of a series of articles by Mr. Thos. Potter under the title "Concrete Simplified."

As the author states at the beginning of his first article, it is not intended to enter into theoretical discussions or even to write for those who are engaged in the larger engineering and building operations to which concrete is so largely applied now. Rather, an appeal is here made to the small builder and the estate owner who have to deal with a large number of small buildings and articles which are needed on the farm and on the country estate. The many ways in which concrete can be used in this direction are scarcely realised yet in this country, and we trust these articles by Mr. Potter—who has long been recognised as the *doyen* of the concrete industry—may prove useful to those of our readers whose work lies rather in the direction of the smaller structures than in that of the larger engineering and building undertakings

After the war there will be a wide field for the employment of concrete not only for cottages, but for other small buildings, especially in rural districts, and not only in our own country, but on the Continent.

RESEARCHES ON REINFORCED CONCRETE BEAMS.

(*Concluded.*)

By OSCAR FABER, D.Sc., A.M.Inst.C.E., etc.

PART VI.

SHEAR TESTS ON RECTANGULAR BEAMS (1910 SERIES)

(*a*) *Description of Experiments.*

The beams were made in accordance with *Figs.* 103 and 104. It will be seen that they contain about 2½ per cent. of steel in tension and about 2 per cent. in compression.

As explained in Part III., section 7, compression steel is necessary if shear tests are to be made on rectangular beams, or the beam will fail by flange stresses due to bending, and not by web stresses.

It will be noticed that variations of the reinforcement include various forms and amounts of bent-up bars, both singly and in combination with stirrups.

They also include beams with no web reinforcement and some with stirrups at different spacings.

The concrete was composed of

⅜-in. Thames ballast	4 parts
Sand	2 ,,
Cement	1 part

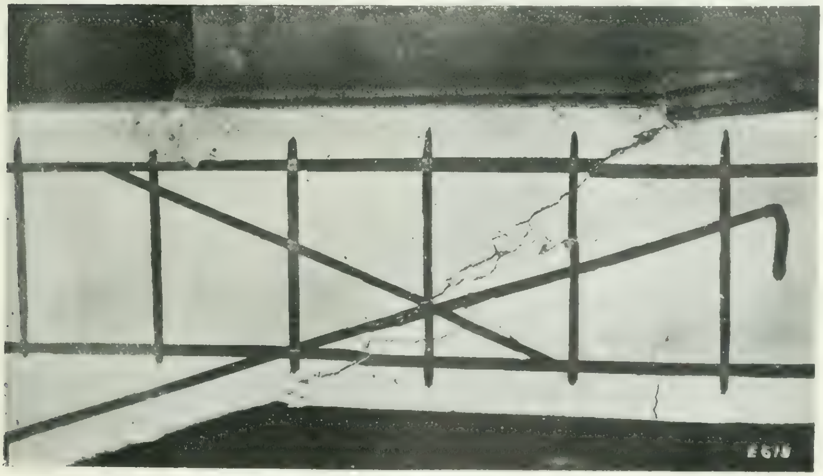


Fig. 100. Beam 8*b*.
Researches on Concrete Beams.

The beams were made at the Northern Polytechnic: Beams 1-4 on January 26th, 1910, and Beams 5-8 on February 2nd, 1910.

They were tested at the age of a month on a 10-ton Buckton machine on a 5-ft. span with two loads 3 ft. apart.

A cube was made from the same concrete as each beam, and given its number, and subsequently tested for crushing.

Spare pieces of the steel were also kept for testing in tension.

(*b*) *Calculations of Resistance by R.I.B.A. Rules.*

Beam No.	Safe shear by			Total.
	Concrete.	Stirrups.	Inclined bar.	
1	$60ba = 60 \times 4 \times 4 = 960$	—	—	960
2	960	—	$0{\cdot}11 \times 16{,}000 \times \frac{4}{12\frac{3}{4}} = 550$	1,510
3	960	—	$0{\cdot}2 \times 16{,}000 \times \frac{4}{12\frac{3}{4}} = 1{,}000$	1,960
4	960	—	$0{\cdot}11 \times 16{,}000 \times \frac{4}{7\frac{1}{2}} = 940$	1,900
5	960	$0{\cdot}1 \times 16{,}000 \times \frac{4}{6} = 1{,}070$	—	2,030
6	960	$0{\cdot}1 \times 16{,}000 \times \frac{4}{4} = 1{,}600$	—	2,560
7	960	1,600	550	3,110
8	960	1,600	1,000	3,560

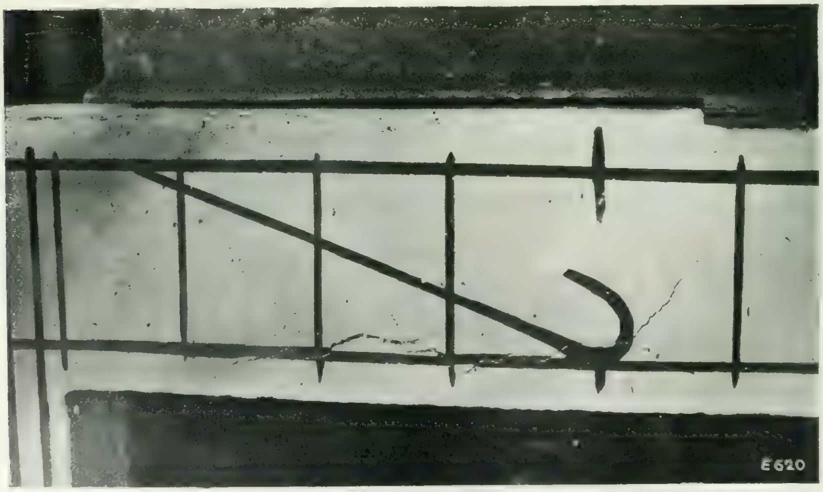
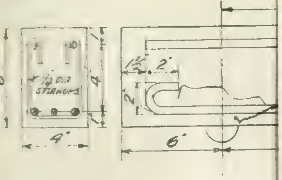
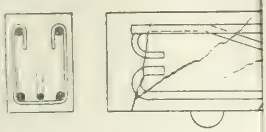
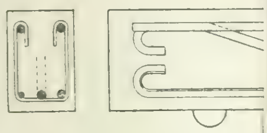


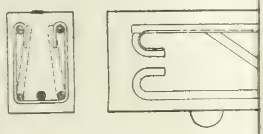
Fig. 101. Beam 8*a*.

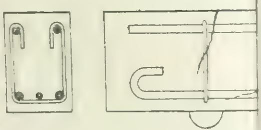
Researches on Concrete Beams.

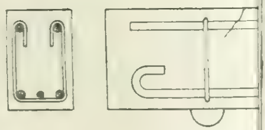


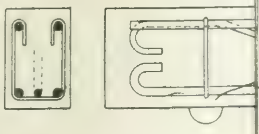


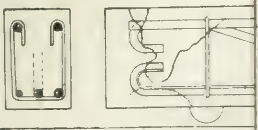








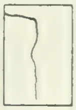


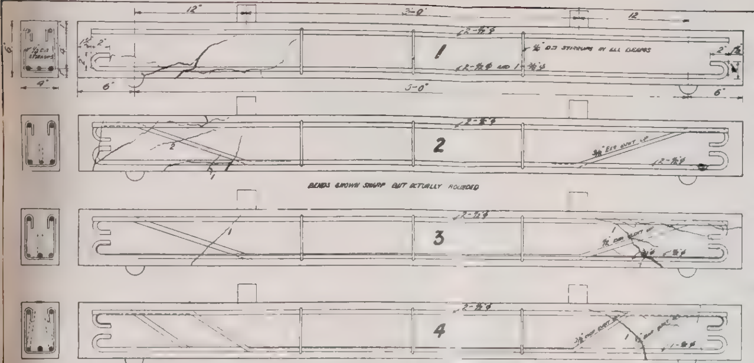


SCALE 3 INCHES

WORK TO FIGURED DIMENSIONS O

WEIGHT OF BEAM 6'0" × 6" × 4" × 150 LBS/C.F = 156 LBS
" STEEL RAIL (DISTRIBUTING LOAD) = 150 "
TO BE ADDED TO MACHINE READ' 306 "

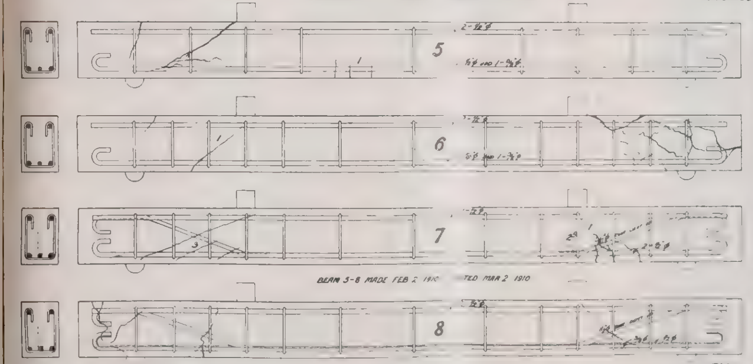
LOADS	CORRECTED LOAD	
6000	6306	CRACK AT L.H. SUPPORT WIDER AT CENTRE THAN UNDER TENSION REINFORCEMENT
6300	6686	BEAM FAILED, WITH SLIPPING OF BARS
8500	8806	FINE CRACK AT LEFT SUPPORT. (1)
10.000	10306	SIMILAR CRACK AT RIGHT SUPPORT. WITHOUT INCREASING THE LOAD THE BEAM FAILED AT LEFT SUPPORT BY CRACK NO 2
6800	7106	FINE CRACKS (1) AT EACH END
7600	7906	BEAM FAILED AT RIGHT SUPPORT NOTE. THE HOOK AT THE BACK (½") WAS TOO NEAR THE EDGE (3/16) AND BURST THE CONCRETE AWAY AND SLIPPED. THIS PUT ALL THE LOAD ON THE ⅝" BAR IN THE BOTTOM, WHICH MUST HAVE YIELDED. THIS ACCOUNTS FOR THE LOW RESISTANCE OF THIS BEAM
8400	8706	CRACK 1 APPEARED CRACKS HEARD BEFORE THIS BUT NOT VISIBLE
8510	8816	BEAM FAILED SUDDENLY. END OF BEAM BURST INTO TWO PARTS BY HOOK OF BENT UP BAR. SKETCH SHOWS CRACK IN END OF BEAM 
6000	6306	CRACKS 1
6000 TO 10000	6306 TO 10306	CRACKS DEVELOPED SLIGHTLY
10900	11206	SEVERAL SMALL VERTICAL CRACKS
12000	12306	DIAGONAL CRACKS DEVELOPING BOTH SIDES
13000	13306	BEAM FAILED
3000	3306	BEAM BEGAN TO DEFLECT
6000	6306	HAIR CRACK
7000	7306	DIAGONAL CRACK (1)
8000	8306	NO APPRECIABLE INCREASE, BUT CRACKING COULD BE HEARD
13000	13306	2 MORE CRACKS
13700	14006	BEAM FAILED
8000	8306	CRACK 1 APPEARED
9000	9306	" 2 "
12000	12306	" 1 DEVELOPED AND CRACKS 3 APPEARED
13000	13306	BEAM FAILED. THE LONGEST OF CRACKS 3 CLOSED UP ON REMOVAL OF LOAD
6000	6306	1ST HAIR CRACK AT BACK OF RIGHT HAND END
16000	16306	BEAM FAILED AT LEFT HAND END



BENDS SHOWN SHARP BUT ACTUALLY ROUNDED

BEAMS 1 - 4 MADE JAN 26 1910 TESTED FEB 23 1910

FIG 103.



BEAM 5-8 MADE FEB 2 1910 TESTED MAR 2 1910

FIG 104.

SCALE 3 INCHES TO A FOOT
WORK TO FIGURED DIMENSIONS ONLY

TEST BEAMS - 1910 SERIES
TESTED FEBY 1910

WEIGHT OF BEAM 6'0" × 6 × 4" × 150 LBS/C.F. = 156 LBS.
" " KNIFE (DISTRIBUTING LOAD) = 150 "
TO BE ADDED TO APPLIED LOAD 306 "

LOADS	APPLIED LOAD	
6000	6306	CRACK AT L.H. SUPPORT UNDER AT CENTRE THEN TOWARDS REINFORCEMENT
6300	6606	BEAM FAILED WITH SLIPPING OF BARS
8500	8806	FINE CRACK AT LEFT SUPPORT (1)
10000	10306	SIMILAR CRACK AT RIGHT SUPPORT. WITHOUT INCREASING THE LOAD THE BEAM FAILED AT LEFT SUPPORT AT CRACK NO 2
6800	7106	FINE CRACKS (1) AT EACH END
7600	7906	BEAM FAILED AT RIGHT SUPPORT NOTE. THE BEND AT THE BACK, 3/4", WAS TOO NEAR THE EDGE (3/16") AND BURST THE CONCRETE AWAY AND SLIPPED. THIS PUT ALL THE LOAD ON THE 3/8 BAR IN THE BOTTOM, WHICH MUST HAVE YIELDED. THIS ACCOUNTS FOR THE LOW RESISTANCE OF THIS BEAM
8400	8706	CRACK 1 APPEARED. CRACKS PASSED BEFORE THIS BUT NOT VISIBLE
8510	8816	BEAM FAILED SUDDENLY. END OF BEAM BURST INTO TWO PARTS BY MEANS OF WEDGE OF BAR. SKETCH SHOWS CRACK IN END OF BEAM
6600	6906	CRACKS 1
6000 10000	6306 10306	CRACKS DEVELOPED SLIGHTLY
10900	11206	SEVERAL SMALL VERTICAL CRACKS
12000	12306	DIAGONAL CRACKS DEVELOPING BOTH ENDS
13000	13306	BEAM FAILED
4000	4306	BEAM BEGAN TO DEFLECT
6000	6306	END CRACK
7000	7306	DIAGONAL CRACK (1)
8000	8306	NO APPRECIABLE INCREASE BUT CRACKS [illegible]
13000	13306	2 MORE CRACKS
13700	14006	BEAM FAILED
8000	8306	CRACK 1 APPEARED
9000	9306	" 2 "
12000	12306	" 1 DEVELOPED AND CRACKS 3 APPEARED
13000	13306	BEAM FAILED. THE WIDEST OF CRACKS 3 CLOSED UP ON REMOVAL OF LOAD
6600	6906	1ST HAIR CRACK AT BACK OF RIGHT HAND END
16000	16306	BEAM FAILED AT LEFT HAND END

(*c*) *Calculations of Resistance by L.C.C. Rules.**

These have already been sufficiently explained, and for this series give the same results as R.I.B.A., except that the shear due to concrete may not be added to this for stirrup or bent-up bars.

(*d*) *Calculations of Resistance by Inclined Compression Theory.*

Beam 1.

As we have top steel, we will use the simple formula

$$S=225\frac{bh^2}{l_1}$$

l_1 being twice 12 in. = 24 in.

$$S=\frac{225\times4\times36}{24}=1{,}350$$

This is conditional on steel at the bottom being carried through to the extent of

$$A=0{\cdot}012\times4\times6=0{\cdot}288 \text{ ins.}^2$$

Note that in most beams 0·51 in.^{2} is provided. Only in Beams 4 and 8 is the steel carried through deficient, and the inclined compression to be reduced accordingly.

Beam 2.

Inclined bar $0{\cdot}11\times16{,}000\times\frac{4}{12\frac34}=$	550
Inclined compression	1,350
	1,900

Note that, as the inclined bar is bent immediately under the load and over the support, the resultant compression is vertical, and has practically no component in the direction of the inclined compression, which is taken in full.

Beam 3.

Inclined bar $0{\cdot}2\times16{,}000\times\frac{4}{12\frac34}=$	1,000
Inclined compression	1,350
	2,350

Beam 4.

Considering a vertical section through the ⅜-in. bar, we have—	
Resistance of ⅜-in. bar $=0{\cdot}11\times16{,}000\times\frac{4}{7\frac12}=940$	940
The inclined compression has to be reduced because the requisite area of 0·288 at the bottom is not supplied, but only 0·2	
Resistance of inclined compression $=1{,}350\times\frac{0{\cdot}2}{0{\cdot}288}$	940
	1,880

Beam 5.

Resistance of stirrups $0{\cdot}1\times16{,}000\times\frac{4}{6}=$	1,070
This causes a concrete stress of $\frac{1{,}070\times2}{4\times4}=133$	
Inclined compression $=1{,}350\times\frac{467}{600}=$	1,050
	2,120

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* For L.C.C. Rules see opp. 87.

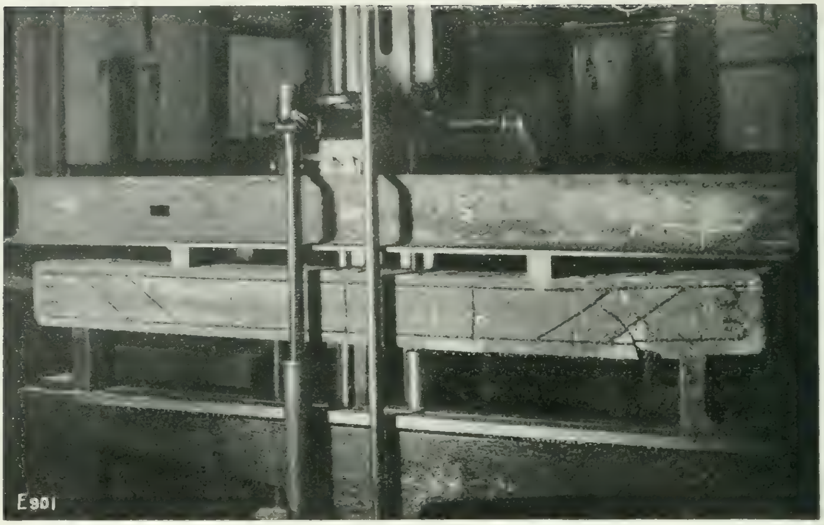


FIG. 105.

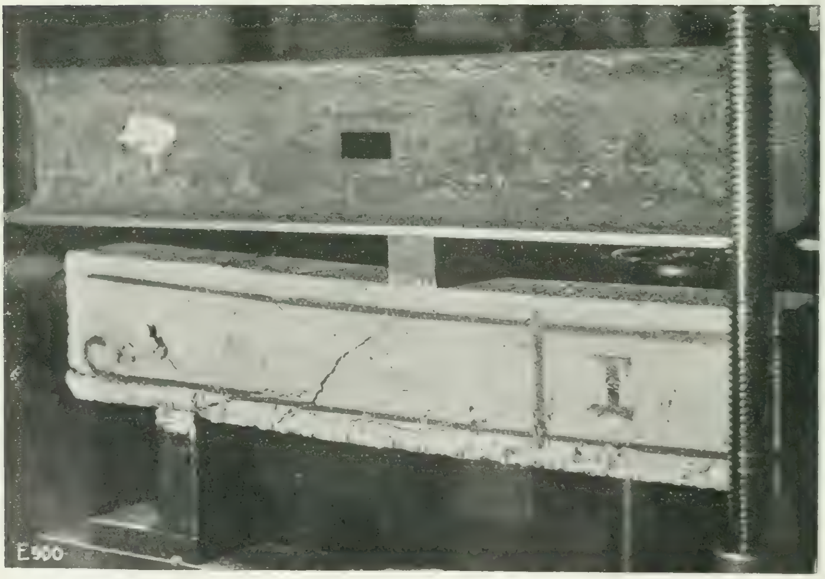


FIG. 106

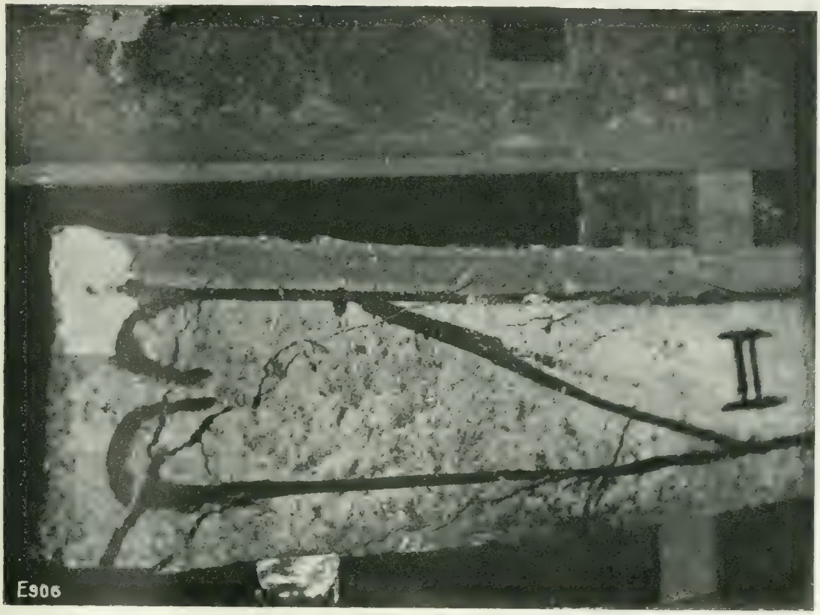


Fig. 107.

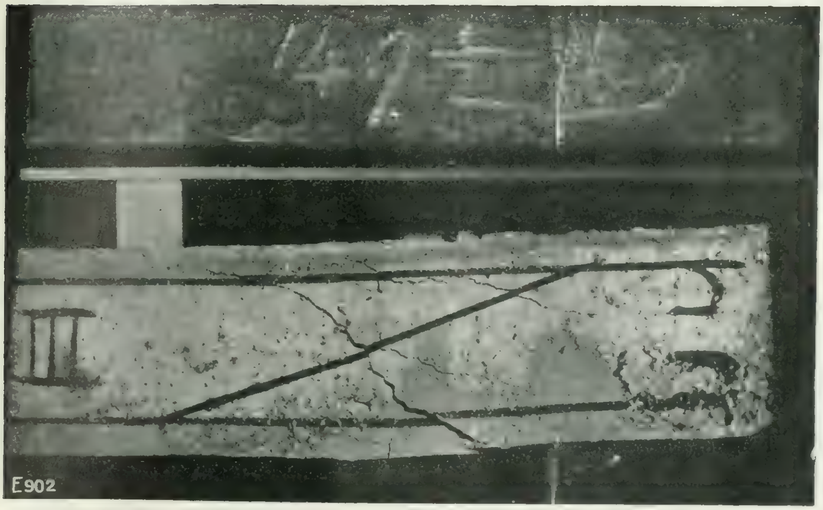


Fig. 108

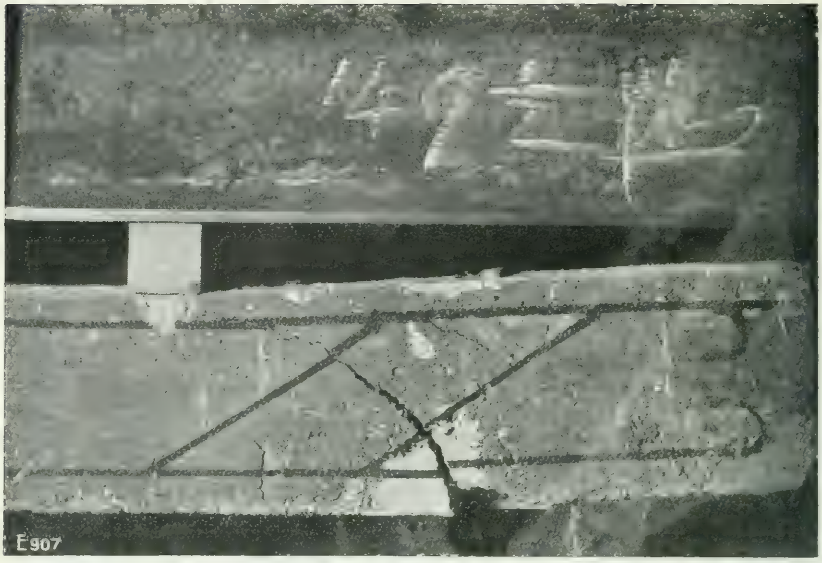


Fig. 109.

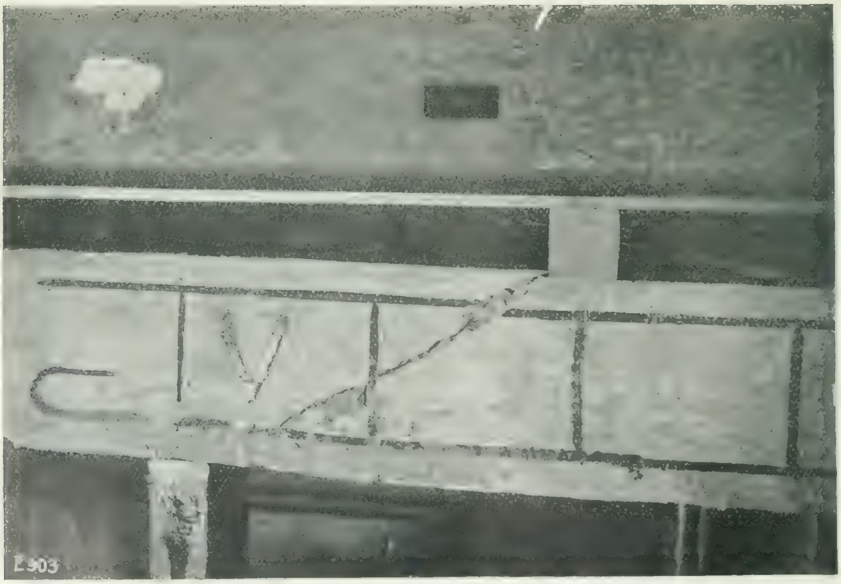


Fig. 110.

Beam 6.

Resistance of stirrups $0{\cdot}1 \times 16{,}000 \times \frac{4}{4} =$	1,600
This causes concrete stress of $\frac{1{,}600 \times 2}{4 \times 4} = 200$	
Resistance of inclined compression $1{,}350 \times \frac{400}{600} =$	900
	2,500

Beam 7.

Resistance of stirrups	1,600
Resistance of inclined bar	550
Resistance of inclined compression	900
	3,050

The last item is reduced as in Beam 6.

Beam 8.

Resistance of stirrups	1,600
Resistance of inclined bar	1,000

We notice that the horizontal component of the inclined compression due to stirrups is 1,600 lb.

The resistance of $1\frac{3}{8}$ in. and $1\frac{1}{2}$-in. bar is $0{\cdot}31 \times 16{,}000 = 4{,}950$, leaving 3,350 for direct inclined compression, which is equal to $4\frac{1}{2}$ in. $\times 4 \times 300 = 5{,}400$ when acting in full

Hence resistance of inclined compression $= 1{,}350 \times \frac{3{,}350}{5{,}400} =$	840
	3,440

(*e*) *Results and Conclusions.*

Comparing the ultimate loads with the resistances calculated by the three methods we have—

Beam Number.	Safe Shear R.I.B.A.	Safe Load.	Ultimate Load.	Factor of Safety.
1	960	1,920	6,606	3·4
2	1,510	3,020	10,306	3·4
3	1,960	3,920	(7,906)	(2·0)
4	1,900	3,800	8,816	2·3
5	2,030	4,060	13,306	3·3
6	2,560	5,120	14,006	2·7
7	3,110	6,220	13,306	2·1
8	3,560	7,120	16,306	2·3

Beam Number.	Safe Shear L.C.C.	Safe Load.	Ultimate Load.	Factor of Safety.
1	960	1,920	6,606	3·4
2	960	1,920	10,306	5·4
3	1,000	2,000	(7,906)	(4·0)
4	960	1,920	8,816	4·6
5	1,070	2,140	13,306	6·2
6	1,600	3,200	14,006	4·4
7	2,150	4,300	13,306	3·1
8	2,600	5,200	16,306	3·1

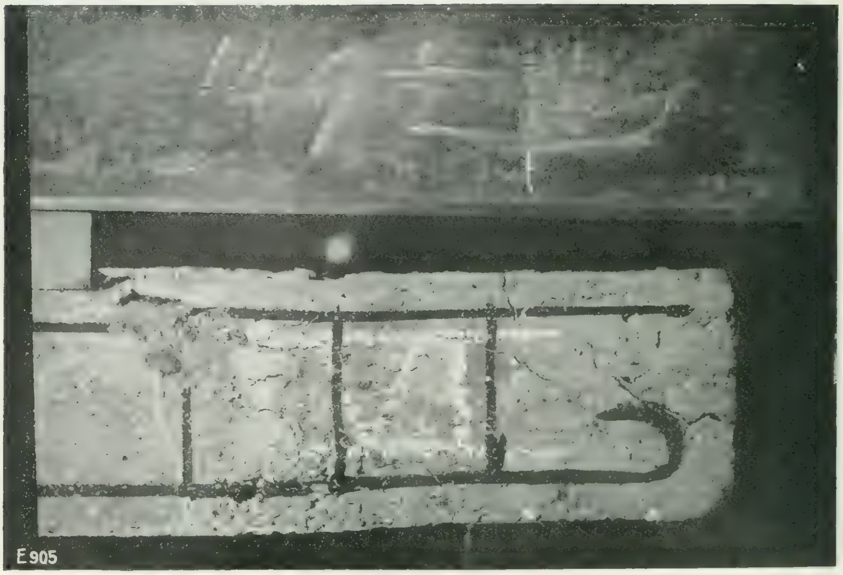


Fig. 111.

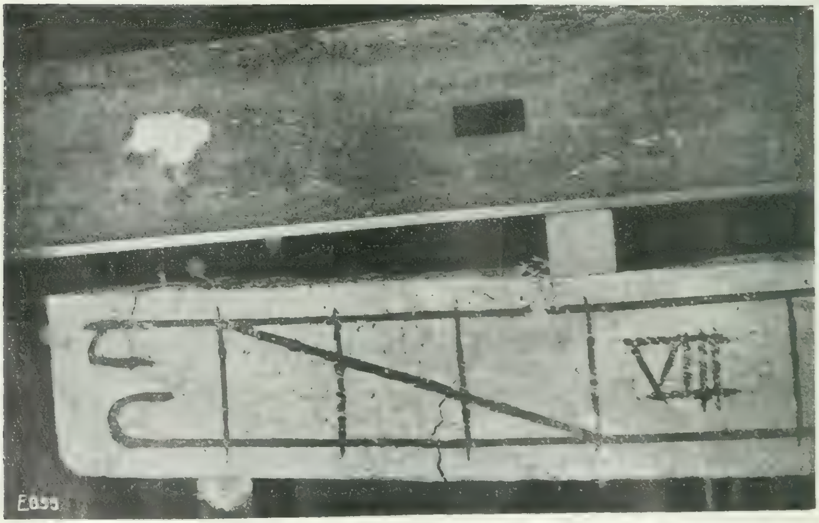


Fig. 112.

Beam Number.	Inclined Compression		Ultimate Load.	Factor of Safety.
	Safe Shear.	Safe Load.		
1	1,350	2,700	6,606	2·5
2	1,900	3,800	10,306	2·7
3	2,350	4,700	(7,906)	(1·7)
4	1,880	3,760	8,816	2·4
5	2,120	4,240	13,306	3·1
6	2,500	5,000	14,006	2·5
7	3,050	6,100	13,306	2·2
8	3,440	6,880	16,306	2·4

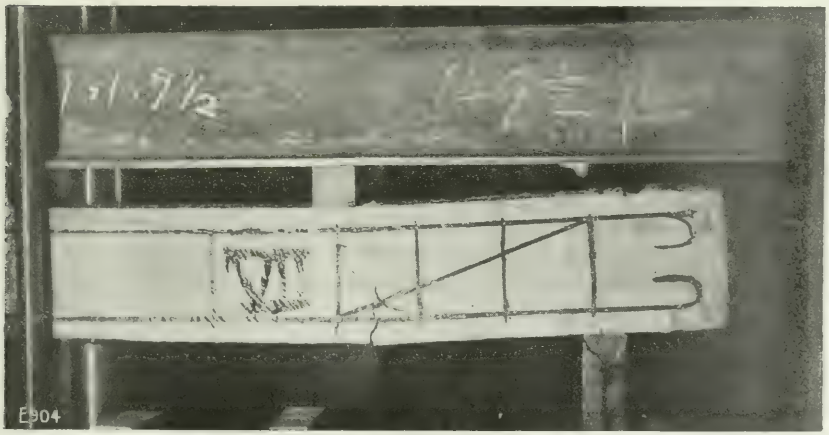


Fig. 113.

It will be seen that the inclined compression theory gives the least variation (2·2 to 3·1).

The results are all low, which is due to a weak concrete.

To obtain the usual resistance with so small an aggregate as ½ in., the proportion of cement should have been increased, and the aggregate was of poor quality. The concrete was also only a month old.

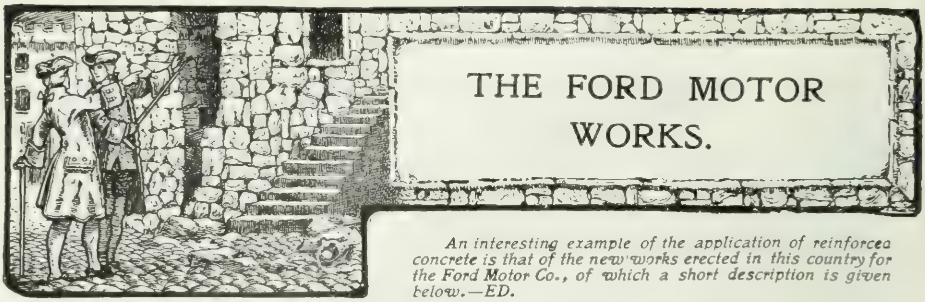
The eight cubes when crushed gave a strength of only 1,310 lbs ins², which only gives a factor of 2·2 on a working strength of 600.

Bearing in mind that these tests were made on 2½-in. cubes, and remembering that it has been established that small cubes give a lower strength than large ones, this figure of 2·2 agrees well with the mean factor of 2·6 found for the beams with the inclined compression theory, and fully accounts for the latter being somewhat low.

It should be recorded that the ⅜-in. bars were found to leave an ultimate strength of 73,000 and a yield point of 55,000, the corresponding figures for the ½-in. bars being 74,500 and 48,500. These values are unusually high.

The results of Beam 3 are bracketed, and should be ignored, as one of the bars was found to be quite close to the edge of the beam, and hence the hook was not effective.

The writer considers the hooks too small, and uses larger ones in his practice.



THE FORD MOTOR WORKS.

An interesting example of the application of reinforced concrete is that of the new works erected in this country for the Ford Motor Co., of which a short description is given below.—ED.

THE growth of the Ford Motor Car industry and the welfare work and profit-sharing plan carried out by the company are subjects of common knowledge and interest, and the factory here described, which is the nucleus of a large London centre is worthy of study and possesses several uncommon features.

The whole of the structure is of reinforced concrete construction, but to gain a more architectural appearance the front elevation and part of one return wall are faced with red bricks and artificial stone dressings, whilst the southern return wall has red brick panels filled in between the constructive members.

The building as erected is but a portion of the proposed completed scheme, which will consist of five stories, and the supporting piers and foundations have been designed and built to carry such future loads. (The drawings reproduced show three of these stories which were to be straightway erected, but the Ministry of Munitions, on account of the war, have only allowed two to be built.)

A reference to the plan shows that the building (*Fig.* 1) is approximately a rectangle of 224 ft. by 122 ft. exclusive of the platform at rear.

It is generally set out on a unit basis of 25 ft. by 25 ft. (the supporting piers being of octagonal form in plan), and thus the whole area is divided into forty-five bays.

The greater portion of the ground floor is occupied by a garage, and access from platform through garage to street is obtained by a series of steel sash sliding doors.

A large washing space next south wall and within the garage is provided, and from the garage two large electric lifts give access for cars to the floor over, and next to each lift an enclosed fire-resisting staircase is placed.

The remainder of the ground floor is occupied by show room, repair stock room, shipping department and hall, and stairs to offices, and these latter, together with the landing hall on first floor, are finished with marble facing and mahogany joinery, and give an expression of dignity commensurate with the importance of the company.

The offices are situated at the north-east corner of the first floor, and the remainder of the building is occupied with repair shop, stores, rooms for welfare work, and a first-aid room. Throughout the building the comfort of the employees has been considered, and drinking fountains in the factory and hot water in their lavatories have been provided.

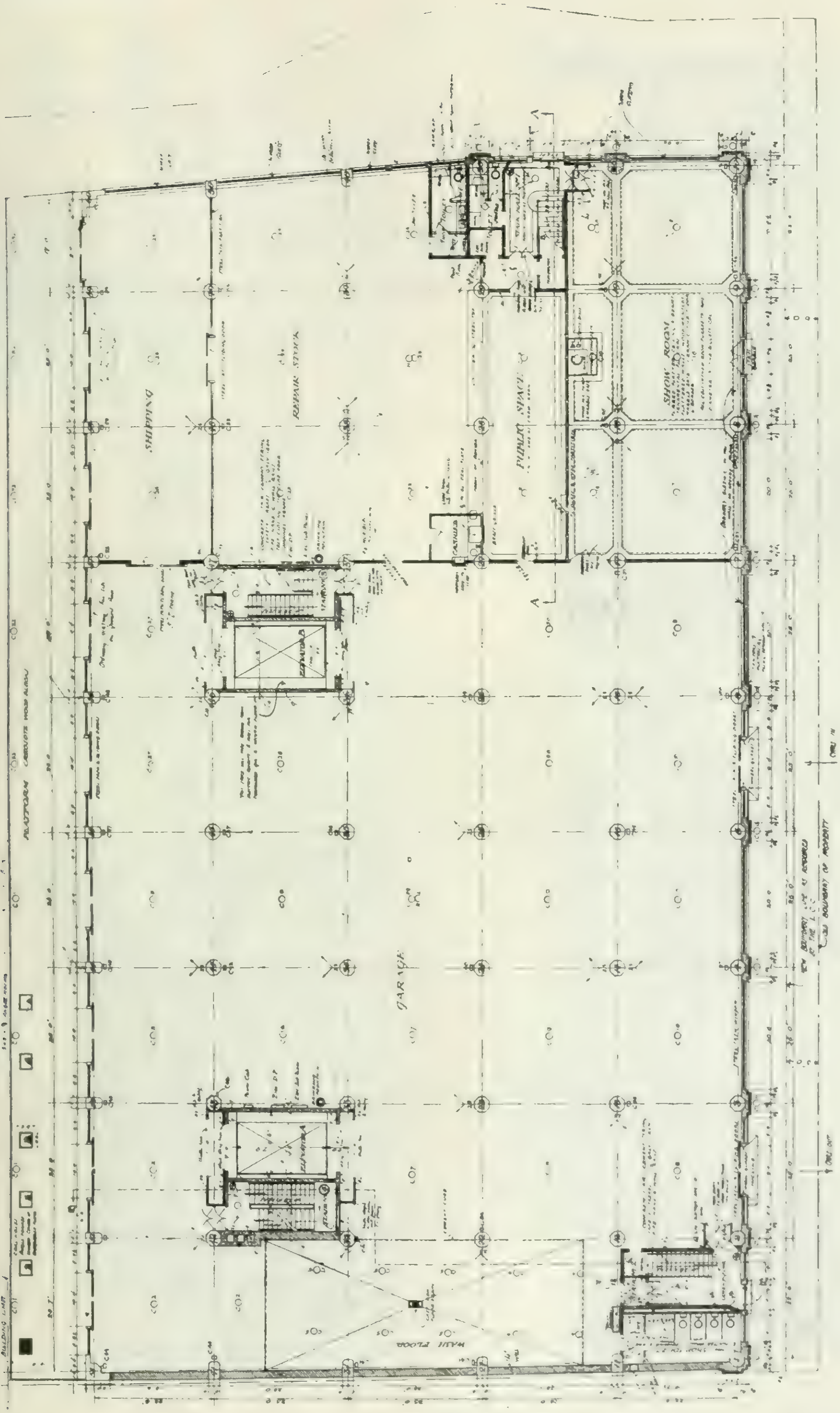
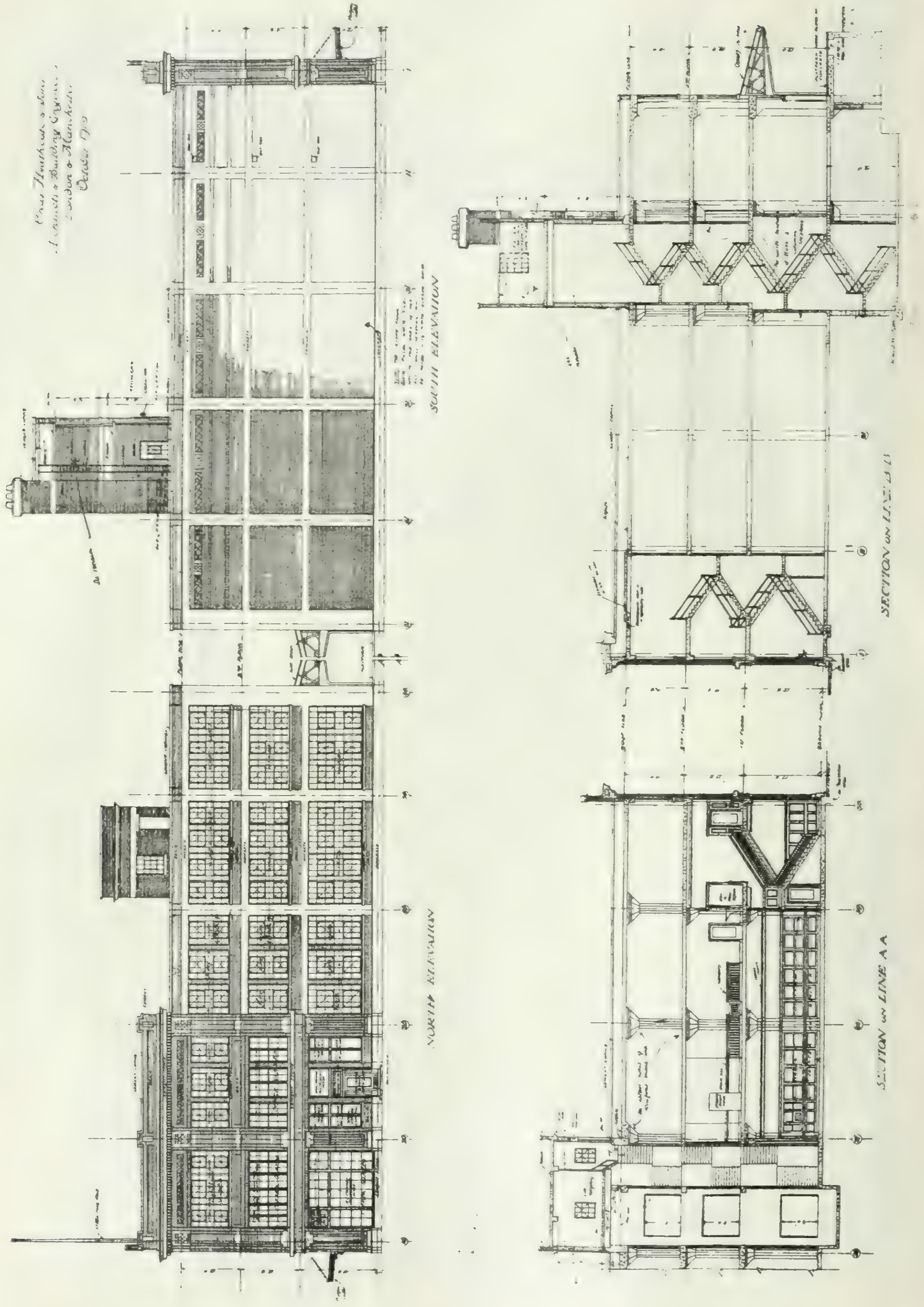


Fig. 1. Ground Floor Plan.
The Ford Motor Works.



Figs. 2 and 3. Elevations and Sections.
THE FORD MOTOR WORKS.

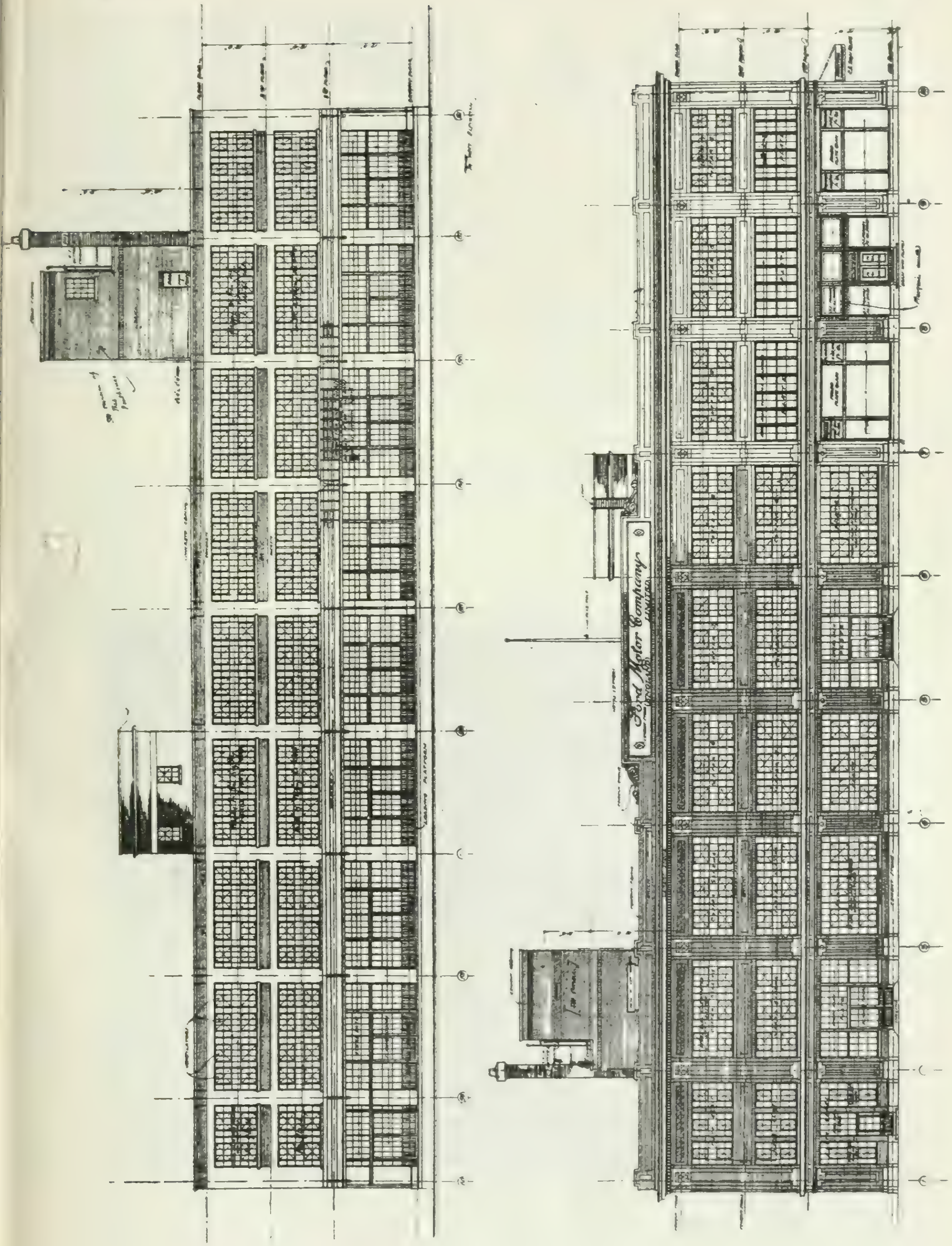


Fig. 4. Elevations.
The Ford Motor Works.

The heating apparatus is in a basement formed at the south-west corner of the building, and large bunker space for coal is provided under the loading platform. In order to facilitate delivery of fuel six large coal shoots have been formed near the edge of platform, so that coal can be shot direct from railway truck to store.

This loading platform is 14 ft. wide, extends the full length of back elevation, and has a railway siding abutting upon it. It is paved with wood blocks and is covered with glazed roof supported by reinforced concrete cantilevers.

The bulk petrol is stored in an underground tank in the yard on the north-west side of the building and is delivered on the " Bywater " system to the point required. For the purpose of charging cars with petrol one bay next front elevation has been enclosed and forms a self-contained dock with armoured doors between it and the garage, and should, therefore, any car fire during filling no possibility exists of the danger spreading to the remainder of building.

The architects for the whole scheme are Messrs. Chas. Heathcote and Sons, of Lloyds Bank Buildings, Manchester, and of 110, Cannon Street, London, E.C., and the whole of the reinforcement was designed in their own offices. The general contractors for the building were Messrs. W. E. Blake, Ltd., of London.

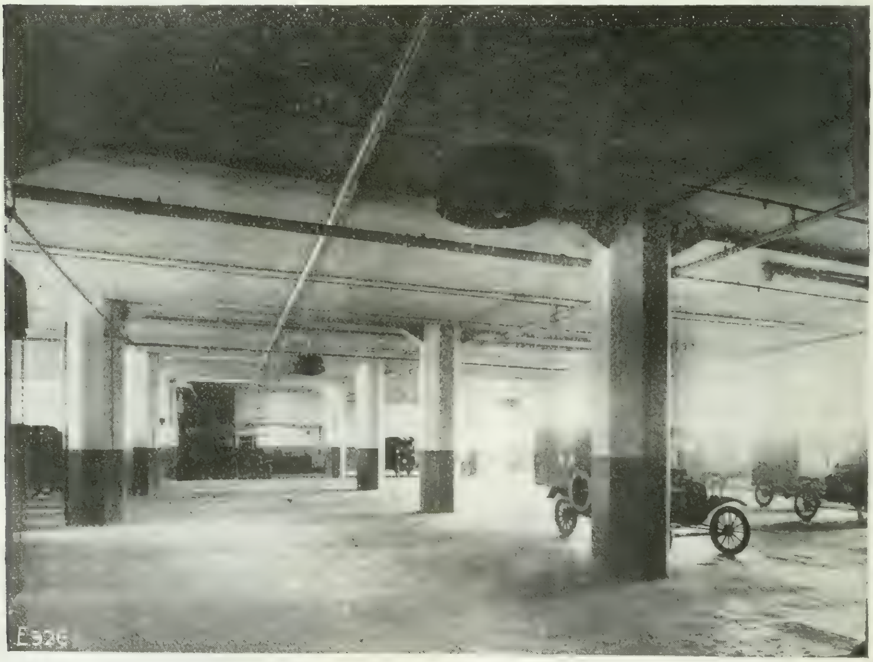


Fig. 5. View of Ground Floor.
THE FORD MOTOR WORKS.

THE SETTING OF CEMENTS AND PLASTERS.

A Discussion at the Faraday Society.

An interesting discussion on the above subject took place last month at a meeting of the Faraday Society, when a number of valuable contributions were made on this important subject. In the following pages we reproduce two of the papers read in full, with an abstract of the contribution made by Mons. Le Chatelier. Further abstracts will appear next month.—ED.

THE MECHANISM OF THE SETTING PROCESS IN PLASTER AND CEMENT.

By CECIL H. DESCH, D.Sc., Ph.D. (University of Glasgow).

ALTHOUGH the use of calcareous cements dates from a very early period of human history, and has attained to so high a development in modern times as to have given rise to an industry of the greatest importance, our knowledge of the scientific nature of the materials and processes involved is even yet imperfect, in spite of many excellent investigations covering various parts of the subject. It is convenient, in a review of our present knowledge, to distinguish between the plasters and simple chemical cements, such as the magnesia cements on the one hand, and the lime mortars, Roman and Portland cements, and similar products, on the other. The chemistry of the substances of the first group is now fairly well known, but the case is different when we turn to the second group. It is only very recently that definite information as to the chemical constituents of Portland cement clinker has been obtained, and even now some points remain in dispute, whilst two distinct explanations of the setting process have been given, and the evidence in favour of either is by no means conclusive. In the present paper an attempt is made to examine these hypotheses and the evidence adduced in their support, and to indicate the nature of the observed discrepancies.

I. PLASTER OF PARIS AND GYPSUM CEMENTS.

It was shown by Lavoisier in 1765 that the setting of plaster of Paris was essentially a process of recombination of the dehydrated gypsum with the water of which it had been deprived in the process of "burning," and that the strength of the mass after setting was the result of the formation of a confused mass of interlacing crystals. The mechanism of the process was not explained until 1871, when Professor H. le Chatelier showed that the hemihydrate $2CaSO_4, H_2O$, readily dissolves in water, forming an unstable solution which is supersaturated in respect to the dihydrate, $CaSO_4, 2H_2O$. Any particles of the latter salt which may be present, probably in the form of unburnt particles of the original gypsum, act as nuclei, and set up crystallisation of the stable dihydrate. It is characteristic of crystals separating from strongly supersaturated solutions that they tend to grow in radial fashion about the nucleus. When the nuclei are sufficiently near to one another, the radiating needles of neighbouring groups interlock, and a mass possessing considerable mechanical strength is obtained, which can only be broken across by breaking the individual crystals. That such a supersaturated solution is actually formed is not only proved by microscopical examination, but was shown by an experiment due to Marignac, who shook ground plaster of Paris with water and filtered after a short interval. The filtrate was five times as concentrated as a saturated solution of gypsum at the same temperature, but it soon became turbid and deposited crystals of the dihydrate. In the ordinary setting of plaster the quantity of water is so small as to be capable of dissolving only a minute fraction of the calcium sulphate, but it is sufficient to form a layer of supersaturated solution around each particle of the hemihydrate, and when this layer deposits its excess of dihydrate the remaining water is available for the solution of a further quantity.

It is certain that the above statement corresponds closely with the main facts of the setting of plaster of Paris of the composition $2CaSO_4, H_2O$, as prepared by any of the usual technical methods. So far as the writer is aware, only one attempt has been made to explain the setting of plaster as a colloidal process. Rohland has suggested that the water is taken into solution in the salt in a colloidal form, and has extended the same explanation to the caking of other salts when powdered and moistened, but the statement is not supported by evidence, and has not been accepted by others.

There are, however, certain facts which indicate that the setting process is not quite simple. It was observed by Cloez that the heat evolved during the setting appears at two different stages, the initial rise of temperature on mixing plaster with water being followed by a stationary period and then again by a rise of temperature. Moreover, the density of the hydrated plaster is different from that which might be expected from the known properties of calcium sulphate and its hydrates. The hemihydrate has a density of 2·75 and the dihydrate of 2·32, and a calculation shows that the latter compound is formed from its components with a contraction of 7 per cent., whilst in practice an expansion is observed, and it is in fact on account of this property that plaster of Paris finds its application in the making of casts, the expansion enabling it to fill the mould completely, and therefore to take an impression sharply. The setting is found to be accompanied by a contraction, followed by a smaller expansion. The experiments of Davis led him to the conclusion that the crystals of the dihydrate which at first separate are not identical with gypsum, but consist of a second, rhombic modification, which subsequently passes into the stable form. It may also be remarked that a part at least of the expansion is only apparent, and is due to the thrusting apart of the growing crystals, producing a porous mass. This effect is common in the growth of crystals from a supersaturated solution, and its existence is obvious from the familiar porosity of a mass of hardened plaster.

The setting of the various kinds of flooring plaster, consisting largely of soluble anhydrite, is in all probability of a quite similar character, and differs from that of plaster of Paris only in regard to velocity. The addition of other salts may also bring about great changes in the rate of hydration and crystallisation of calcium sulphate, potassium sulphate, for instance, accelerating the process, and borax retarding it. Rohland has shown that the accelerators are substances which increase the solubility of gypsum, and the retarders are those which diminish the solubility. Colloidal substances may delay the setting considerably, and these facts are made use of in the preparation of many technical plasters.

2. SUBSTANCES THE SETTING OF WHICH RESEMBLES THAT OF PLASTER.

It was also shown by Le Chatelier that other substances which are capable of forming unstable supersaturated solutions will set in the same manner as plaster of Paris. Thus, anhydrous sodium sulphate dissolves readily in water, and if precautions are taken to prevent too rapid solution and consequent rise of temperature, a highly concentrated solution may be prepared at practically constant temperature. This solution is unstable, and the hydrate separates in characteristic interlocking masses of crystals.

Various cements composed of a mixture of an insoluble metallic oxide and a solution of the chloride of some similar salt of the same metal are in technical use. For example, a mixture of zinc oxide with a concentrated solution of zinc chloride yields a strongly supersaturated solution, from which the oxychloride slowly crystallises. Magnesium oxychloride, prepared in a similar manner, forms the basis of many cements, and may be assumed to set by a process of crystallisation, although Kallauner considers that the ease with which the chloride is extracted from the solid mass by means of alcohol, and the fact that the free magnesia in the mixture cannot be completely converted into carbonate by carbon dioxide, point to the formation of a solid solution of hydroxide and chloride rather than of a definite oxychloride. A microscopical study of the setting process does not appear to have been made, although it would have some interest in relation to the problem of the dental cements, some of which have an analogous constitution.

Barium metasilicate is another salt which forms supersaturated solutions and is capable of setting when mixed with a small proportion of water. The product is the crystalline hydrated salt $BaSiO_3$, $6H_2O$. The orthosilicate undergoes hydrolysis, forming the hydrated metasilicate, $Ba_2SiO_4 + 15H_2O = BaSiO_3, 6H_2O + Ba(OH)_2, 8H_2O$. Owing to the comparatively great solubility of the silicate, the setting resembles that of plaster, and the mechanical strength of the product is not comparable with that of a hydraulic cement, although in the case of the orthosilicate the chemical reaction is quite similar to that which constitutes the principal part of the hydration of a Portland cement. The product is crystalline, and consists of interlocking bunches of needles.

3. LIME, CEMENT, AND CEMENTS OF THE PORTLAND CLASS.

The hardening of a simple lime mortar, composed only of slaked lime and sand with water, is a mere process of desiccation. The calcium hydroxide forms an apparently structureless mass, which may be either colloidal or minutely crystalline, and the cohesion of this mass furnishes the necessary strength. The sand merely prevents the cracking which would otherwise take place during the contraction on drying, by subdividing the line into thin layers. As time goes on, the calcium hydroxide may recrystallise to a certain extent, whilst those portions of the mass which come into contact with the atmosphere may be converted into the crystalline carbonate, but neither of these changes is essential to the hardening of the cement. There is no chemical reaction between the lime and the sand. On the other hand, when pozzolanic substances are added to the mortar, such as the volcanic earths of the Mediterranean which were used by the Greeks and Romans, the trass and ground tiles which were employed by the Romans in more northern regions, or the burnt brick and ballast added to this day in India, a chemical reaction takes place between the lime and the active or soluble silica which is the essential constituent of all pozzolanic materials, and calcium metasilicate is formed.

Portland cement is a more complex material. The constitution of the clinker has been established by the brilliant investigations of the Geophysical Laboratory staff at Washington. The compounds which are or may be present are tricalcium silicate, $3CaO$, SiO_2; calcium orthosilicate, $2CaO$, SiO_2; tricalcium aluminate, $3CaO$, Al_2O_3; pentacalcium trialuminate, $5CaO$, $3Al_2O_3$; and free lime CaO. Campbell has recently given reasons for believing that tricalcium aluminate is rather to be regarded as a solid solution of lime in the pentacalcium trialuminate, but this does not materially affect the present problem. Not more than three of the above-mentioned compounds can be simultaneously present in the clinker in a state of equilibrium, but since the components do not reach the temperature of fusion during the process of manufacture, it is actually possible for small quantities of one or more additional constituents to occur in commercial clinker. It does not appear, however, that clinker made in a rotary kiln departs very widely from the state of equilibrium.

An examination of the ternary equilibrium diagram shows that the clinker will contain a ternary eutectic, there being two such eutectics within the usual range of the composition of clinker. The microscopical examination of transparent sections of clinker does not reveal the presence of any eutectic, but this is simply due to the minuteness of the structure, much overlapping occurring even within the thickness of a thin section. When, however, the specimen is polished on one surface only and lightly etched, as in the examination of metals, the eutectic structure is clearly revealed. The writer has published one such photograph, and Mr. T. Hattori, working in the writer's laboratory, has since obtained very beautiful eutectic structure of Japanese clinker. The calcium aluminate which is chiefly present as a constituent of this eutectic is consequently in a finely divided form, and therefore in a condition to react readily with water.

According to the explanation of the setting process put forward by Le Chatelier in 1887, the ground cement reacts with water in such a way that the silicates and aluminates are hydrolysed, the stable compounds being the hydrated metasilicate, $CaSiO_3$, $2{\cdot}5H_2O$, and a hydrated tetracalcium aluminate, $4CaO$, Al_2O_3, $12H_2O$, the excess of lime liberated by the hydrolysis forming calcium hydroxide. Microscopical examination of the reactions of the constituents with water led to the conclusion that the process was strictly analogous with that of the setting of plaster, an unstable supersaturated solution of the basic silicate, for example, being formed initially, followed by rapid crystallisation of the stable phase in the form of radiating needles. In reference to this, it should be remarked that the process is largely dependent on the ratio between solid and water, and that in hydration experiments on a microscope slide the quantity of water used is relatively much larger than in the gauging of cement in practice, and that this fact probably accounts for certain discrepancies recorded by different observers.

The alternative hypothesis was proposed by W. Michaelis in 1893, and expanded in a later paper. On this view, whilst the chemical reactions assumed are those which were shown to take place by Le Chatelier, the physical conditions are supposed to be different. The hydrated metasilicate is considered to form, not a mass of radiating crystals, but a gelatinous mass or gel, the gradual dehydration of which brings about the hardening of the cement with time. The aluminate crystallises much more readily than the silicate; but even this is regarded as forming a gel when the solution is sufficiently supersaturated—that is, when the quantity of water is small, as is the case in the practical utilisation of cement. The presence of gelatinous material at an early stage of the setting process is readily observed. It has been photographed by Stern, and the increase of size of the current particles by absorption of water and consequent swelling of the gelatinous sheath which forms around them has been described by Ambronn and may be readily confirmed. According to Colony, a reaction subsequently takes place between this early gelatinous material and the remaining constituents of the cement, and a secondary amorphous product is formed, the desiccation of which is the cause of the hardening. At a later stage, crystals of calcium hydroxide, calcite, and zeolites make their appearance.

An attempt to distinguish between the various possible colloidal products has been made by Keisermann, using the method of staining with organic dyes. The results indicate that the gelatinous sheath consists of calcium metasilicates, which compound also occurs in the form of small needles, whilst the calcine hydroxide and aluminate assume the crystalline form. These staining results with colloids depend largely on the concentrations of the substances concerned, and the writer, possibly not working under precisely similar conditions, has not succeeded in confirming all of Keisermann's results. The dependence of the observations of the size of grain has been pointed out by Wetzel. Other experiments in which stains were used led Blumenthal to the conclusion that the metasilicate and aluminate were first formed in a crystalline condition, so that the cement sat like plaster, but that a colloidal gelatinous silicate was subsequently formed, and strengthened the mass by binding the crystals together and filling the pores.

The process of setting of the individual constituents, as well as of commercial clinker and artificial mixtures, has been examined in great detail in the laboratories of the U.S. Bureau of Standards. The staining method has been applied as a means of identification, and the hydration has been followed under various conditions of temperature and proportion of water. The general conclusion is that the initial set is due to the hydration of the aluminates, and that the only stable hydrated aluminate is the tricalcium salt, the water content of which is variable. Either the 5:3 compound or monocalcium aluminate, if present, undergoes hydrolysis, and the tricalcium salt is formed together with free alumina, the latter separating in a colloidal hydrated form. In presence of an excess of water, the product may be crystalline, as in Le Chatelier's original experiments, but with a restricted supply of water an impervious layer of the amorphous material may be formed, retarding the further action of water. The silicates are hydrated much more slowly, the products being calcium hydroxide and an amorphous jelly of hydrated silicate. The hydroxide may be crystalline or amorphous, according to the concentration and to the rate of hydration. The hydrolysis of the silicates is even considered to proceed so far that gelatinous silica is liberated. The subsequent conversion of a part of the gelatinous mass into crystals is considered to result rather in a loss than in a gain of strength.

It would appear that conclusions based on the examination of mixtures of ground material with water on a microscope slide must not be applied indiscriminately to the conditions of actual practice. The ratio of water to salts is of the utmost importance in determining the nature of the products, although the chemical reactions may be the same in both cases. An attempt has been made by Von Weimarn to show that the passage from the colloidal to the crystalline condition is a continuous one, and that the difference consists only in a difference of size of the particles. This may be accepted in the sense of considering colloidal materials as being in such a fine state of division that the surface forces are comparable in their effect with those which depend on mass. It is then not difficult to understand that the degree of supersaturation of the solution may determine whether the product which separates shall have a definite crystalline form or shall be, in the ordinary sense, amorphous. The real nature of the colloidal condition has been unnecessarily obscured by the barbarous terminology which has been adopted by so many writers on the chemistry of colloids, and especially by the school of Ws. Ostwald. Stripped of these uncouth technical terms, the study of colloids appears far less formidable, and it is to be hoped that the present discussion may, by putting in relief the views of the supporters of the two rival hypotheses as to the setting and hardening of cement, lead to a recognition of the true facts of the case, and to an elimination from the subject of the complications which owe their origin largely to a defective terminology.

A final reference should be made to the action of catalysts on the process of setting. Whilst many observations on this point are on record, the subject has not been sufficiently investigated, and affords a promising field for research. The remarkable changes in the velocity of setting which take place spontaneously in commercial ground cements, even when stored out of contact with air, are of great technical importance and no satisfactory explanation of them has yet been given.

THE SETTING OF CEMENT IN ITS RELATION TO ENGINEERING STRUCTURES.

By BERTRAM BLOUNT.

THE question of the setting of cements of all sorts has been a subject of investigation for many years, and, except in the simple case of plaster of Paris, remains unsettled. I propose to deal chiefly with the practical aspect as it appears to the engineer. Before doing this, however, I should like to say a word or two on the present state of the theory of the subject.

In the first place the term cement is elastic, and it is wrong to suppose that colloids like casein should be excluded. Their behaviour may throw light on the mechanism of setting of more important cements. Next, how is one to define setting? Generally it involves hydration, but is the induration due to loss of water, as in the case of clay, to be excluded? I take it that, broadly, setting does not connote hydration, and with this narrower definition we must be content. Taking the typical case of plaster of Paris, it has been established that a supersaturated solution is formed, that interlocking crystals are deposited from it, and that the released water passes on to perform the same function with adjacent particles This naturally leads to a consideration of whether strontium sulphate and barium sulphate set in the same way. The low solubility of both, especially the latter, would seem at first glance to negative the supposition, but as both are found crystalline in nature, the question is not superfluous. Coming to industrial cements of the Portland cement class, the question is much more difficult. I am not aware that any definite proof has been given that the constituents of Portland cement form supersaturated solutions and set in the manner accepted as true for plaster of Paris. A fair indication of this is found in the fact that there are two schools of thought concerning setting, the one crystalline, the other colloidal. I profess myself strongly neutral, as evidence on each side appears inconclusive.

As setting is a gradual process, there is no such thing in reality as a setting point or setting time. But in practice it is convenient to fix an arbitrary condition, which is called the "setting point," and to call the time occupied in reaching this condition the "setting time." With minor cements, such as those of the plaster of Paris class, it is not usual to define the condition or the time rigidly. It is generally sufficient to recognise that ordinary plaster of Paris "goes off" quickly and needs rapid handling, and that other calcium sulphate cements, setting more slowly, can be manipulated in a more leisurely way and require a considerable time to harden. With the more important cements, of which Portland cement is the chief instance, something less rough and ready is required. In consequence numerous methods have been devised and put into tentative use. One of the most mechanically attractive was that of my friend Professor John Goodman, who in 1887, as far as I remember, constructed a machine consisting of a metal trough on which ran a loaded roller pulled by clockwork and having a central fin. The trough was filled with cement and the ends of the roller rolled on the edges of the trough with the fin dipping in the plastic cement. As the cement set, and the roadbed became harder, the fin with its roller was gradually lifted upwards and eventually rode on the surface of the set cement. The rate and time of setting were automatically recorded on a diagram drawn by a pencil passing through the centre of the roller. Certainly a neat idea, but the difficulty common to all methods of determining setting time came in. There was no definite point of time when the fin on the roller ceased to make an impression, and thus the accuracy aimed at by this ingenious machine was greater than the nature of the material allowed. I hope that Professor Goodman will correct me if I am wrong, as I write from memory.

In practice the only apparatus of any value for determining the setting time of cement is the Vicat needle—or one of its modifications, such as the British standard needle formerly used—which is too well known to need description. By simple means of this kind cements can be classified quite as closely as their nature allows, having regard to the fact that the setting of cement is not like the setting point of a metal —and that, too, is a progressive phenomenon—but a gradual process.

Even with this modest standard of attainment the determination of the setting point of cement is beset with pitfalls. Cement is scarcely ever used neat, and yet its setting point is invariably determined neat, and I for one see no means of using any other method. The best that can be hoped for is that a cement with a given setting time will behave with some sort of relation thereto when it is made into mortar or concrete. But consider the difficulties here. An ordinary Portland cement will require about 22½ per cent. of water to make a plastic mass. When mixed with standard sand in the proportion of 1 : 3 it will need about 10 per cent. of water, reckoned on the mixture, in order to make a plastic mass—*i.e.*, roughly double the amount used when it is neat. The mechanism of setting will be very different under these different conditions, but there is more than that. The aggregate, sand, stones, and the like, will be mechanically in the way of progressive hydration; that, however, is a trifle compared with the thermal effect. The setting of cement generates heat, which in large masses and with quick-setting cements may cause a considerable rise in temperature. Indeed, the method of measuring rise of temperature has been suggested as a mode of determining the setting time—chiefly in Germany; anything more lunatic is difficult to conceive. Where the cement is slow setting and the proportion of aggregate is considerable, say 6 or 8 to 1, as it generally is, the rise of temperature is not large unless the cement is so unsound that it contains what is conveniently termed "free lime." That idea may be dismissed with regard to cement made under modern conditions. What is of more moment is the influence of temperature on the rate of setting of cement. If the temperature is high the rate of setting is correspondingly high and may be too high for satisfactory construction.

Cements used in Madras at a tropical temperature, and in winter in Canada, obviously are being employed under very different conditions, and it is the business of the cement manufacturer to provide a suitable material which shall act, not as it does in a temperate climate, but in the place and under the conditions of actual use; he must be a little proleptic. I admit that the task is a hard one; proleptical tasks mostly are, but that the difficulties can be overcome is shown pretty clearly by results. When not only ordinary concrete but ferro-concrete has to be considered the difficulties with regard to setting increase rapidly.

A 30-ton block may be made for harbour work and allowed to lie in the yard for six months, and if it does not set hard at once no one is much the worse, provided that the cement and aggregate are of good quality.

With ferro-concrete the matter is different. A reasonable time must be allowed for such things as piles, as they are not put immediately to use and may lie in the yard, but the ordinary ferro-concrete structure is monolithic, and the engineer responsible for the structure must know the period necessary for proper setting.

To sum up this part of the question of setting of cement in general, it appears to me—to put extant knowledge in the shortest way—that little is known about the mechanism of setting, save in the case of plaster of Paris; that the most important cement, Portland cement, is tested for setting time neat, and is never used neat, and that there is no quantitative relation between its setting time neat and its setting time in concrete.

CRYSTALLOIDS AGAINST COLLOIDS IN THE THEORY OF CEMENTS.

By HENRY LE CHATELIER (Paris).

I HAVE always opposed the theory which attributes the hardening of cements to certain colloidal properties of the material, as being devoid of sense. People evade defining a colloid, but they seem to take the word in the sense of a body capable of hardening. And then the explanation comes down to this: cements harden because they have the property of hardening.

After this general remark let us note that Graham, the originator of the discovery of the bodies designated as colloids, had recognised the existence of two sorts of different solutions. The one kind gave on evaporation crystallised bodies called *crystalloids* (sea-salt, sugar, etc.), the other gave amorphous gelatinous materials called *colloids* (gelatinous silica, gum, etc.). He further recognised that the crystalloids are diffused when dissolving and that the colloids are not.

More recently Zsigmondy showed with the aid of the ultramicroscope that the colloidal solutions are not true solutions, but merely suspensions of very finely divided, rigorously insoluble matter. These suspensions are opaque, milky, or transparent, according to the fineness and the abundance of the particles so suspended in the liquid. The diameter of the true colloids approaches a millionth of a millimetre, and is always much less than 0·001 mm.

All very minute insoluble bodies give such colloidal suspensions, but surely it is not sufficient cause to give a particular name to bodies, the only singular properties of which are insolubility and fineness.

These very minute bodies possess one quite special and very important property, however, which entitles them to being classed separately—that is, the property of absorbing the soluble bodies which are held in solution by the liquid with which they are wetted.

This absorptive power is a particular case of much more general properties which all very fine bodies possess. Chemically, a body in the form of an impalpable powder behaves quite differently from the same body in the form of big lumps. The former is more under the immediate sway of surface tension.

The fact has long since been acknowledged that all chemical phenomena depend directly upon diverse forms of energy, of one of which chemistry does not speak as a rule—that is, the surface energy which is measured by the product of the surface tension (or capillary tension) and of the free surface of the body. In magnitude, surface tension is generally infinitely small when compared with the other forms of energy. Thus the surface energy of a gram-molecule of water, 18 grams, in the form of a single sphere, just corresponds to $6{\cdot}3 \times 10^{-8}$ kg. calorie. Now the vaporisation of a gram-molecule of water absorbs 10 calories, and its combination with lime liberates 10 calories. Its surface energy is therefore only equivalent to the one hundred-millionth part of heat—that is to say, absolutely negligible.

If instead of taking the water in the form of a single sphere we divided it into a vast number of little globules, each of one-millionth of a mm., their surfaces and consequently their total superficial energy would become 330 million times greater, and thus equivalent to 2 calories; that is to say, the surface energy would be of the order of magnitude of the quantity of heat which water evolves in its various chemical reactions. The surface energy in that case would no longer be a negligible factor.

As regards solids in suspension in a liquid, there is no direct method for measuring the surface tension at the constant between the solid and liquid. Certain indirect considerations lead us to admit, however, that this tension may become a hundred times greater than that of water. The superficial energy will be increased in the same ratio and its influence will become appreciable for dimensions of the order of a ten-thousandth millimetre—dimensions much greater than those of chemical precipitates.

A solid crystal in very fine grains will certainly have all the properties of colloids, as long as it retains its fineness; but it will rapidly lose the latter, as soon as it is brought in contact with a liquid capable of partially dissolving the substance. The energy of dissolution will be increased by the whole superficial energy of the crystal; there will result an increase in the solubility of the fine crystals, and a supersaturated solution will be produced, from which larger crystals will soon be separated.

Every soluble body, even if existing in very fine division, progressively loses its colloidal properties when it is maintained in contact with a liquid in whch it is somewhat soluble; its transformation will be all the more rapid, the greater the solubility. It is only insoluble bodies, therefore, which can preserve the extreme state of subdivision which corresponds to the colloidal state. For the same reason, bodies which are properly called colloids never show any discernible crystalline form, because the crystalline orientation supposes a certain mobility of the material within the solvent.

We come to the hydraulic mortars. Are the products of their hardening colloidal or are they not? Let us first take the case of plaster. When plaster has set, we can never discern any crystals in the material, even under the strongest magnification of the microscope. That does not prove that no crystals are formed; perhaps they are too small to be recognised. Crystals are discernible at the end of several weeks; after several years they are sometimes visible to the naked eye. We can, moreover, make the crystals in hardening plaster visible from the beginning, when we gauge the plaster with alcoholic water (instead of pure water); the setting is then retarded and the crystals can better develop.

The calcium aluminates, which play an important part in the hardening of rapidly setting cements, are hydrated at the same rate as the plaster, and they give likewise a whitish mass in which crystals are not discernible. If, instead of gauging the aluminate with little water, we put a few isolated grains of the aluminate into a large volume of water, we observe that the grains soon become surrounded by long crystals of hydrated aluminate, which are always easily visible under the microscope and can sometimes directly be seen by the eye.

Calcium silicate alone causes a difficulty in these considerations, and this is important, because the silicate is the essential element in the hardening of Portland cement. The microscope has never enabled us to see hydrated calcium silicate. Its crystals are certainly very minute; numerous analogies prevent us, however, from denying their existence. The hydration appears to be exactly the same as in the case of barium silicate. In both, crystals of hydrated lime or baryta are plainly visible; crystals of barium silicate can always be seen with the aid of a lens. By analogy, hydrated calcium silicate should crystallise as well; but being much less soluble than the barium compound, the crystals will be too minute to be discernible. In the course of time the dimensions of the crystals must increase considerably, as in all similar instances. The colloidal state has nothing to do with the hardening of the cement.

I may here be allowed to recall the explanation of the hardening of cements which I gave thirty years ago, and which does not appear to have been weakened yet:

The anhydrous compounds of cements, not being in chemical equilibrum when in contact with water, are more soluble than the same hydrated compounds. For this reason they give rise to the formation of a supersaturated solution from which the hydrated compound may rapidly crystallise. The liquid, being no longer saturated, can redissolve more of the anhydrous compounds, and the whole mass can thus crystallise progressively by passing through a stage of transitory dissolution in a limited volume of water, which, at any given moment, cannot maintain in solution more than a small portion of the total mass of salts present. The crystals which are deposited from the supersaturated solutions always appear in the shape of extremely elongated needles, which have the tendency to group themselves in spherolites about certain centres of crystallisation. The entanglement of all these crystals is the only cause of the solidity of the mass. They become welded with one another when the reciprocal orientation is suitable; they adhere by simple contact, as do all solid bodies when really resting upon one another. Finally, friction at the points of contact, even in the absence of all adhesion, suffices to produce a great strength of mechancal resistance, such as is found in all tissues and fabrics whose solidity has no other origin. The finer and the more elongated the crystals, the more numerous the points of contact and the greater the frictional resistance. The greater the area of contact, the more developed the adhesion. The progressive growth of the crystal dimensions by the mechanism which I have suggested increases the part played by adhesion while diminishing that due to friction.

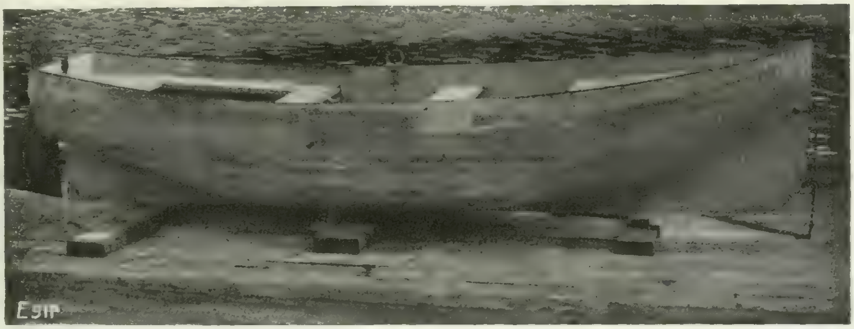


Fig. 1. The *Zeemeeuw* in 1910, when 23 years old.

CONCRETE VESSELS IN HOLLAND.

An interesting contribution to the literature on concrete ships is a pamphlet published last year by Mr. A. A. Boon, Civil Engineer, Amsterdam, in which, after reviewing what has been done in the various countries, Mr. Boon devoted considerable space to the activities in his own country—Holland. It is that part of the publication which is dealt with in the accompanying article. We are indebted to Mr. Boon for permission to reproduce the illustrations. Our abstract from the pamphlet has been prepared by Dr. A. B. Searle.—ED.

THE first boat of reinforced concrete to be built in Holland was constructed in 1887 by Gebrüder Picha-Stevens at Sas van Gent. The *Zeemeeuw* (*Fig.* 1), which was built about the same time, is still in regular use by the Amsterdamer Fabrik von Cementeisenwerkev, notwithstanding several collisions with other large ships and that it has been frozen in the ice each winter. This vessel has proved to be unusually stable—an important feature when winding canals have to be negotiated by boats drawn by animals.

In 1909 a 10-ton boat, the *Juliana* (*Figs.* 2 and 3), was designed and built by A. A. Boon, of Amsterdam, around an old wooden vessel which had become unseaworthy. A netting was constructed of ¼-in. bars spaced so as to form meshes 2 in. square. This was fitted outside the old hull and was covered with a fine wire netting and then filled in and covered with impervious concrete to a thickness of 4 in. It was found impossible to remove the old woodwork which had formed the centering without damaging the concrete, so the wood was cut away where this could be done conveniently, but a considerable part of it was left as an integral part of the renovated vessel and was incorporated into the fittings. This mode of renovating old boats proved to be quite satisfactory for vessels of small dimensions, but it cannot be recommended for larger ones as the use of both wood and concrete makes the boats too heavy in proportion to their dead-weight capacity.

Mr. Boon built a larger concrete vessel, the *Antoon* (*Figs.* 4 to 6), in 1910; this was an open lighter of fifty tons dead-weight capacity for the removal of ashes, etc. It was built with double walls, after Gabellini's (Italy) designs, though in several important respects it differed from any of Gabellini's boats and is more monolithic in character. The outer shell was made by pouring the concrete between the shuttering and the inner shell and by plastering the concrete over a fine wire network. The main reinforcing members consist of a large number of bars spaced uniformly. The inner and outer shells are connected by numerous webs or tie-pieces of concrete arranged longitudinally and transversely so as to divide the space between the shells into a series of closed compartments. Additional webs are arranged at each end of the vessel. The total length of the lighter is 63 ft. 4 in., its breadth 15 ft. 9 in. above and 12 ft. 4 in. below, and its total height 4 ft. 2 in. It weighs thirty-six tons. The hold is 39 ft. long and is separated from the stem and stern quarters by cross walls, the latter being covered by decks. The shells are only $1\frac{1}{4}$ in.

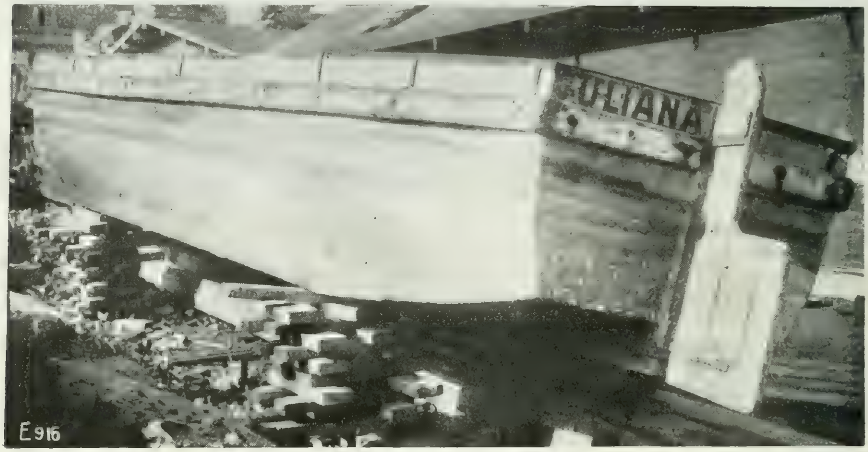


Fig. 2. The *Juliana* in 1910, after five years' use.

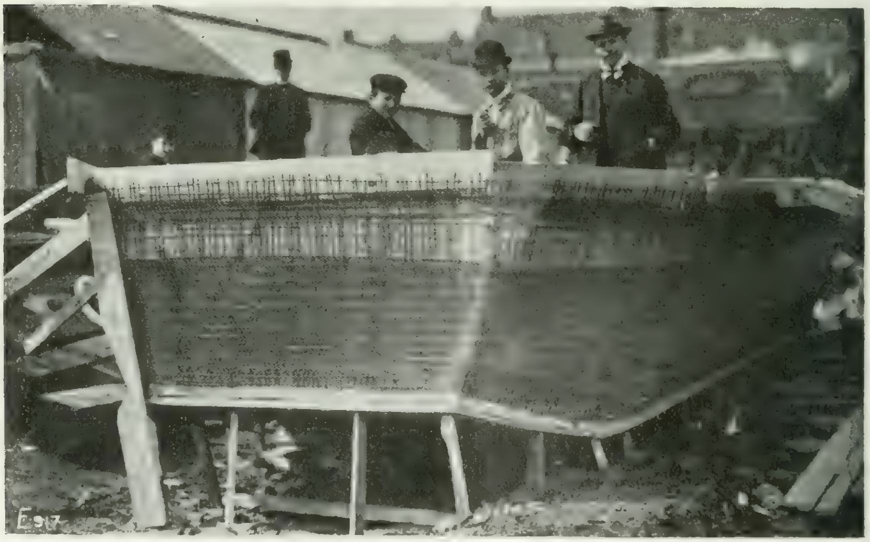


Fig. 3. The *Juliana* during construction.

thick. When in the water, the unladen vessel is 18 in. below the water line—a figure which is too high for a boat of the dimensions given.

The shuttering for the bottom and outer shell and for the walls of the intermediate compartments was built first and was then "filled" with a thin fluid concrete. This was allowed to harden slightly and the shuttering for the end walls and decks was then fixed and these parts of the vessel cast in a similar concrete, special care being taken to secure a good joint between the new and older concrete On removing the shuttering it is easy to see whether

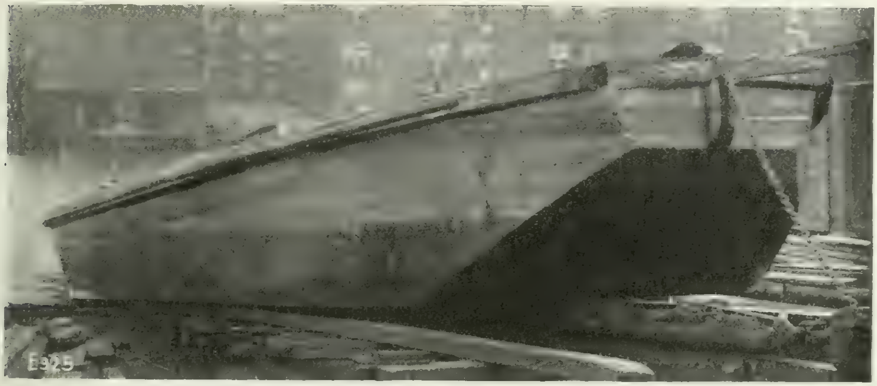


Fig. 4. The *Antoon* (built in 1910) after six years' use.

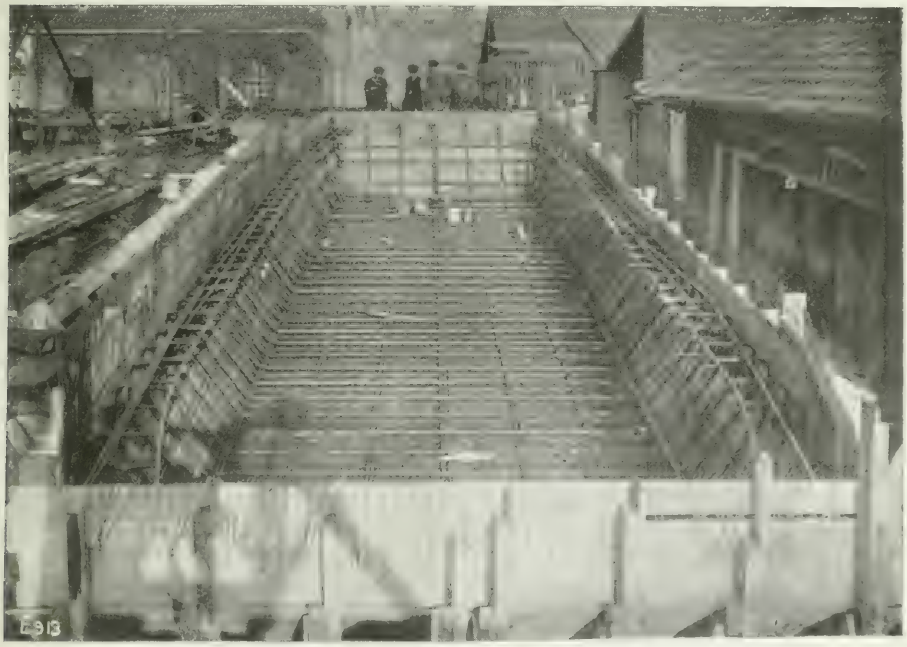


Fig. 5. Reinforcement of [illegible]-ton lighter.

the casting has been properly executed, and any places which may require strengthening may have a light wire netting attached and covered with concrete. The covering of the reinforcement of the inner shell with concrete was effected with the greatest possible care as there was no simple means of proving that it had been well done. The outside of the vessel was grouted smooth and the general quality of the workmanship was proved by the fact that when the vessel was launched no leaks appeared. This vessel has been in daily use for the last seven years and has not required any repairs.

Most of the concrete vessels now in use have walls 1½ in. to 4 in. thick, but some of the smaller boats built by Gabellini have only 1-in. walls. A thickness exceeding 2½ in. appears to be excessive and makes the vessel ride too deeply in the water; hence the desirability of making the walls as thin as possible notwithstanding the corresponding increase in cost. For the same reason the use of a double shell is undesirable except in boats or pontoons which are liable to frequent and violent impacts from other vessels. In Mr. Boon's opinion it is better to divide the whole vessel into a series of water-tight compartments, each being accessible only through manholes in the deck, than to waste space by the use of small compartments between two shells, as in the *Juliana*. This arrangement avoids the necessity of the longitudinal ribs in the walls of the vessel, but requires one or more permanent partitions in the hold. Mr. Boon considers that these partitions are necessary for taking up the strains and stresses caused by the varying pressures applied to different parts of the vessel, particularly when it is at sea or if it is loaded more heavily on one side than on the other.

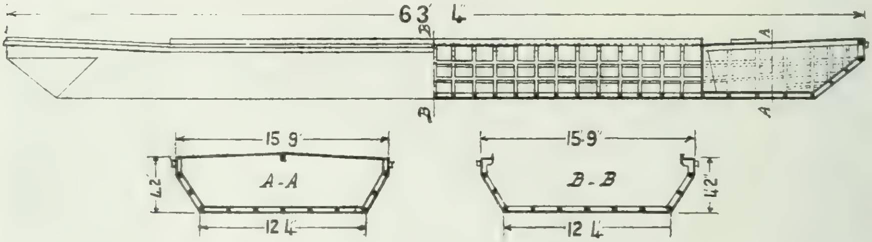


Fig. 6. Details of 50-ton Lighter.

Such an arrangement proved quite efficient in a semi-rotary pontoon in which the breadth must not exceed 10 ft., the immersed depth 14 in., whilst the length was 50 ft.—dimensions which impose special difficulties of design, but which were satisfactorily overcome by constructing the vessel with thin walls tied by webs at frequent intervals attached to a longitudinal partition running down the centre of the pontoon.

A steerable lighter (*Figs.* 7 to 10), constructed entirely of reinforced concrete, and now in use at Amsterdam, is 68 ft. long, 15 ft. wide above, and 12 ft. 4 in. below, with a dead-weight capacity of sixty tons. Its walls have an average thickness of 1¼ in., but both stem and stern are more strongly built in order to resist impacts with other vessels and with the sides, etc., of the canal. This vessel is divided into a series of closed compartments by means of three longitudinal and thirty-three transverse partitions (*Fig.* 9), all suitably reinforced with light bars arranged to form a network. To protect the exterior, a fixed rim or fender of wood and half-round iron was used. Four double hatchways give access to the interior of the vessel.

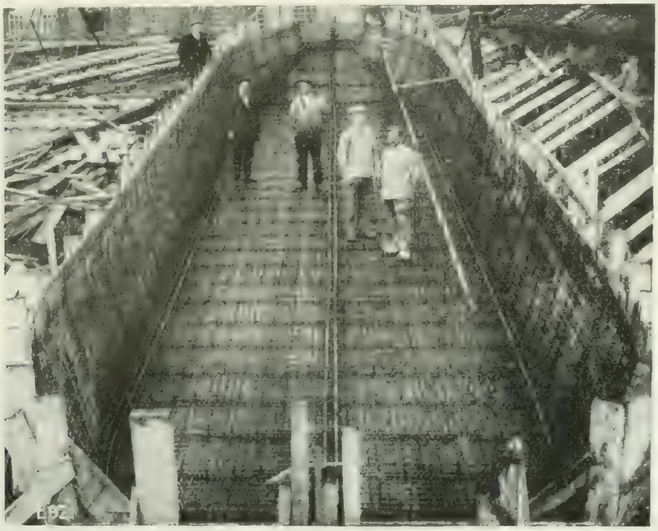


Fig. 7. Main Reinforcement of 60-ton Lighter.

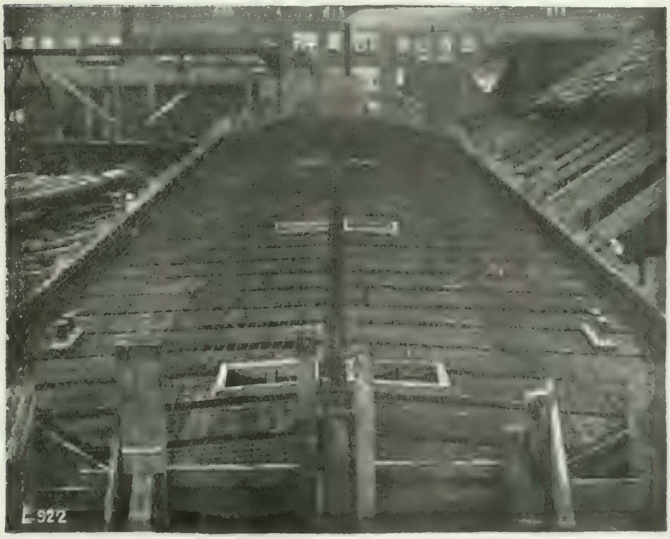


Fig. 8. Deck Reinforcement of 60-ton Lighter.

A type of lighter which is extensively used on the Dutch canals for the transport of ashes, dredger-sludge, and other refuse is shown in *Figs.* 11 to

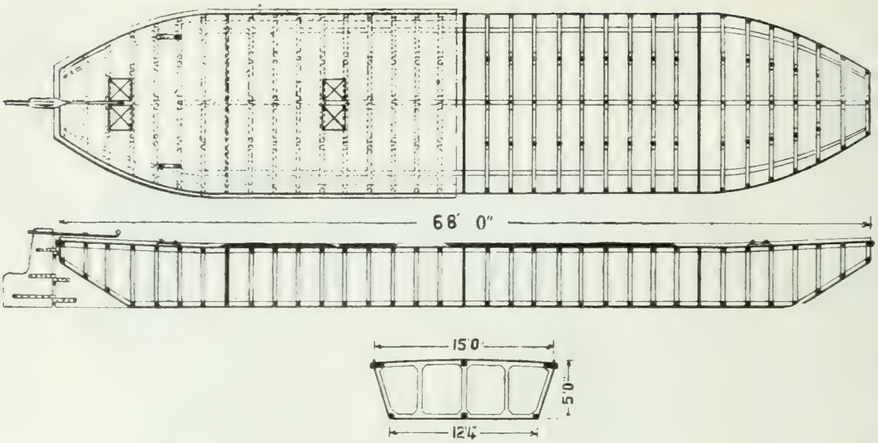


Fig. 9. Details of 60-ton Lighter.

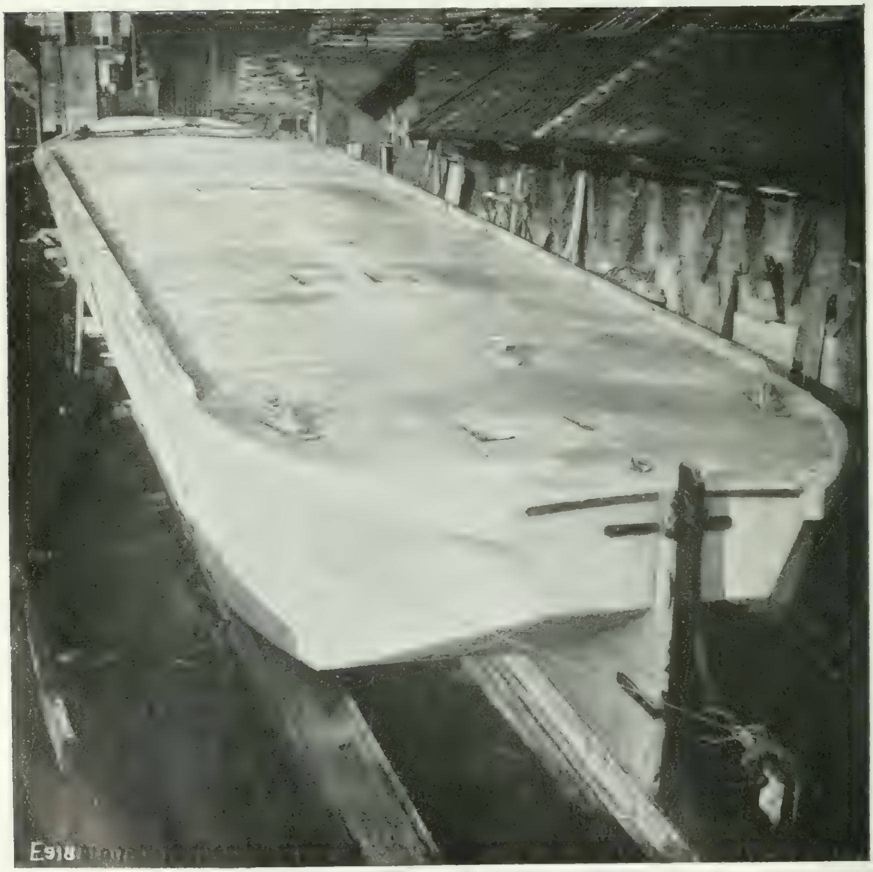


Fig. 10. 60-ton Lighter ready for launching.

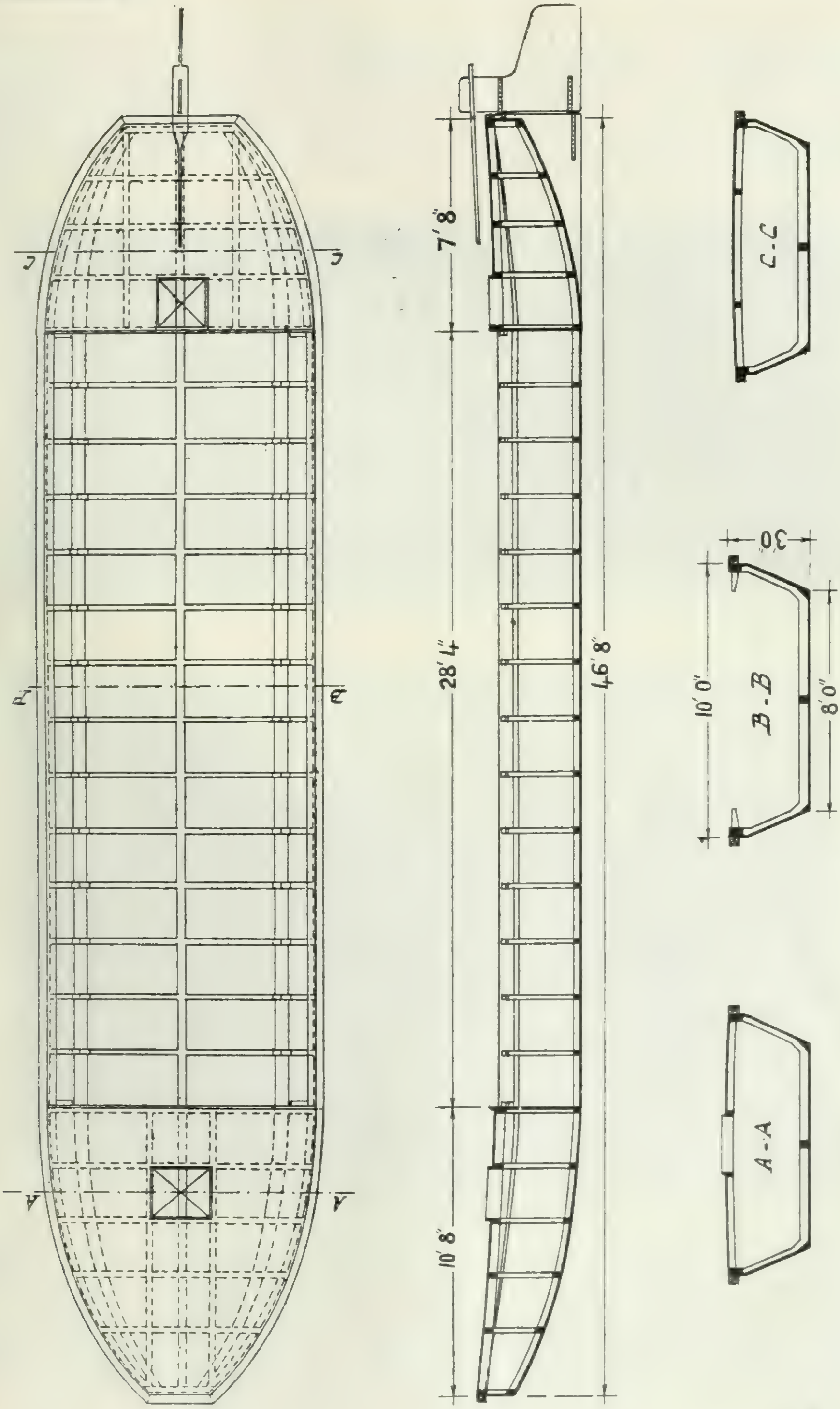


Fig. 11. Details of Barge for ashes and mud

13. These lighters are 46 ft. 8 in. long, 10 ft. wide, and 3 ft. high, with $1\frac{1}{4}$ in. walls. They have a carrying capacity of fifteen tons.

Concrete is extensively used in shipbuilding in the Dutch East Indies, where one firm makes a speciality of canoes and lighters of 90—180 tons deadweight capacity, motor boats up to 60 ft. long, and various pontoons for carrying steam-cranes and other heavy machinery.

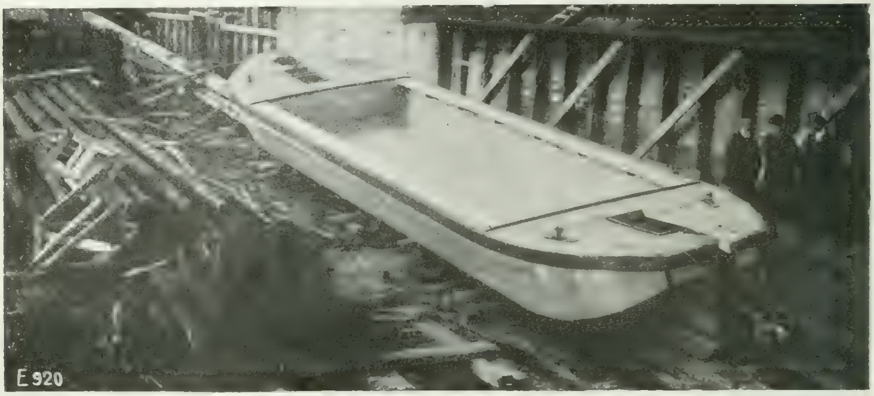


Fig. 12. Lighter for ashes and mud.

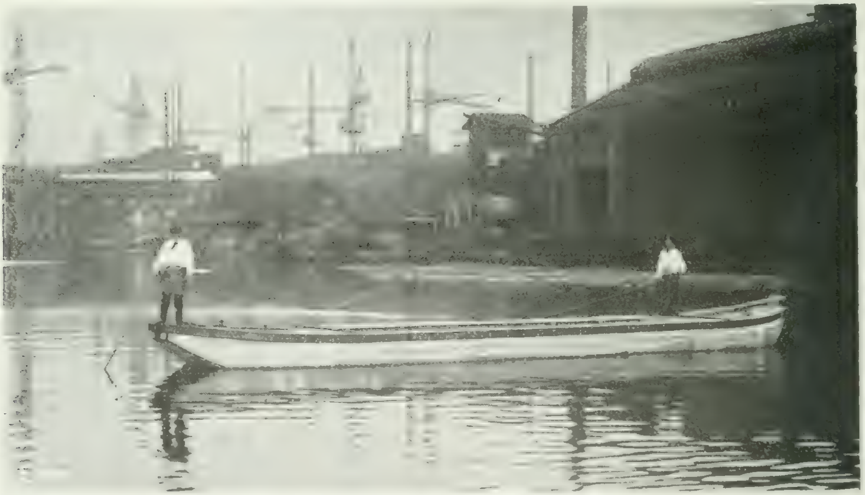


Fig. 13. A Lighter for ashes and mud.

Mr. Boon is opposed to the construction of small motor-boats of reinforced concrete as their weight is too great in proportion to their capacity. For larger vessels, on the other hand, the weight of concrete is less important and is more than counterbalanced by the other advantages of the material. Among the larger motor-boats constructed of concrete is one of 100 tons dead-weight capacity, built by Picha, of Ghent, and measuring 86 ft. by $14\frac{3}{4}$ ft. by 7 ft.

Careful examination of two concrete boats which had been in regular use for seven and eight years respectively showed that no growths occur if the surface of the concrete is smoothed before launching. If the surface is left very rough barnacles or algæ may adhere to it. The smoothly finished concrete also reduces the skin friction of the vessel when moving through the water, and it ensures the reinforcement being kept free from rust a matter of considerable importances with respect to the durability of concrete vessels

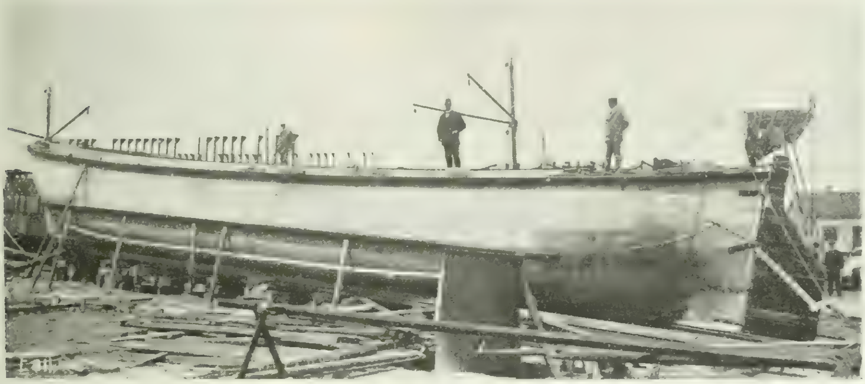


Fig. 14. A Barge being built at Malmo.

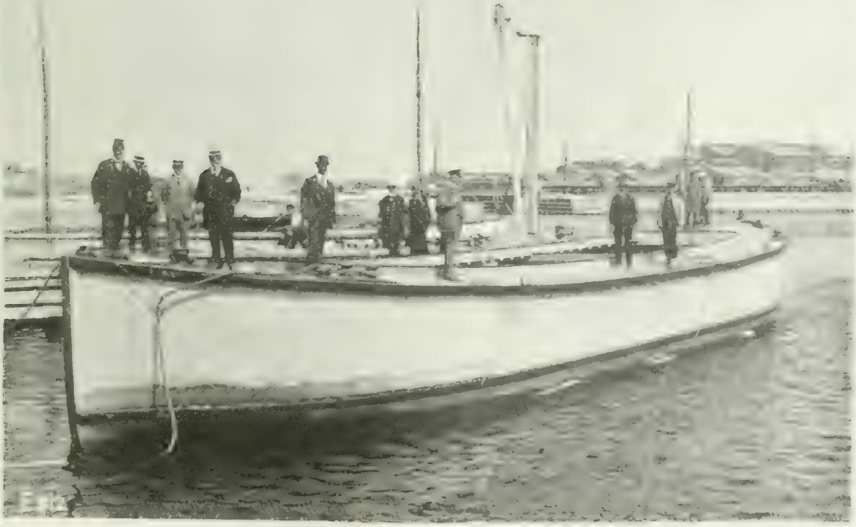


Fig. 15. The same Barge when launched

It is clear that Dutch shipowners already appreciate the value of concrete for shipbuilding purposes and that there is a good future for this material, provided sufficient attention is paid to keeping the weight of the vessel as small as possible consistent with strength and durability. The most satisfactory method of doing this is to cast the vessel with thin walls and with a suitable reinforcement, and to omit all constructional details which do not serve a definite static purpose.

A Swedish Concrete Vessel.—By the courtesy of Mr. A. A. Boon we are able to reproduce two photographs of a 200-ton concrete vessel recently built by him at Malmo for the Skanska Cementgjuteriet, of Stockholm. (See *Figs.* 14 and 15.)

This vessel is 85 ft. long, 20 ft. 10 in. wide, and 8 ft. high, with walls 1¼ in. to 1½ in. thick. The dead-weight is seventy tons, and ten tons of reinforcement have been used in its construction.

MEMORANDUM.

A Reinforced Concrete Keel.—In a recent issue of the *Motor Ship and Motor Boat* an interesting description is given of how a lead keel of a 4-ton sailing yawl was rebuilt in reinforced concrete. The following is the description given by the writer of the article :—

"The boat in question was a 4-ton sailing yawl, but had shared the fate of many others and had sacrificed her lead keel to make inside ballast for Fritz. Consequently I purchased her at a very low figure, and as the alterations were all economically effected her total cost was very low.

"In considering such craft, supplying the keel determines the success of the proposition, consequently I resolved to make this myself of reinforced concrete. Having secured a quantity of scrap metal, I constructed a wooden box mould and erected stumps in it to allow for the keel bolts. At the foot of each of these I placed a block of wood to make a housing for the bolt heads. On these I left large iron washers or plates to give a firm hold for the keel bolts. Into the mould I put a layer of concrete and bedded some long castings in it to form a backbone. On this I kept cramming concrete and adding metal as ingeniously as possible, so as to get the greatest strength and weight.

"When the mould was filled flush I waited some weeks and then broke it apart, leaving the keel standing. Preparatory to putting it under the yacht, I chipped it and smoothened it off with cement and drilled the stumps from the bolt holes. Having the keel under the yacht, I fitted the bolts through. I found that before I could get the keel a good fit against the yacht I had to remove it several times and bevel the top; but then with a thick layer of red and white lead mixed on top I bolted it up permanently.

"At this stage I realised the convenience of concrete, as in casting the keel I quite forgot the rudder shoe, but it was a simple job fitting it and cementing it in.

"The keel, when finished, caused great comment among the folk about, and there was much curiosity as to how it would work with the large spread of canvas the yacht had hitherto carried. Tnings seemed to quieten down when a 4-ft. bowsprit appeared forward and an auger aft through her port quarter."

CONCRETE SIMPLIFIED.

By THOMAS POTTER.

A Practical Guide to the General Use of Concrete.

INTRODUCTION.

THIS series of articles is not intended to deal with concrete of an intricate nature or high order, involving algebraical calculations and theoretical deductions, but to its adaptation for buildings of an unpretentious character which form the great majority of those required at the present time in many parts of the country, and also for many purposes for which it is adapted in preference to other materials but which appears to a great extent to be imperfectly understood.

The Author has only dealt with materials and their application that have come within his experience during many years in practice, when he has been able on numerous occasions personally to ascertain the results arising during long intervals of time that have elapsed since the work was executed.

I.

AGGREGATES.

CONCRETE consists of two elements, the material to be joined together, called the aggregate, and the cementitious material, whatever it may be, called the matrice. The aggregate should be of an imperishable nature, of sufficient strength for the purpose it is intended for, and capable of resisting compressive stress, and the matrice of a suitable description to combine with the aggregate. The latter should be by preference irregular in shape, that its particles may interlock and with the matrice form a homogeneous mass. It should be clean—*i.e.*, free from clayey or other deleterious substances.

Concrete in modern times was at first used only for foundations of buildings and similar purposes, and for these Thames gravel or ballast was in London and near thereto the only material employed. Concrete was almost unknown in London and elsewhere seventy years since. A London architect, writing in the *Builder* in 1848, says he had used concrete for foundations in London, but was unable to in the provinces, as no one appeared to know anything about it. It had, however, been used in isolated cases for a long time previous thereto. About fifty years since it was adopted for walls of buildings and almost entirely in the suburbs of large towns and in country districts, while gravel being used exclusively in London it was assumed that this was the only suitable aggregate elsewhere. As, however, gravel was not always obtainable, other materials were employed and found to be equally suitable for the purposes required. The relative value of various aggregates is, and always has been, a disputed point; obviously the character of most buildings erected in London and other populous centres is very different from the class of unpretentious buildings which form the large majority required in country districts. The former are of a greater height, have to support much heavier loads, and are occupied by many more persons. As a result, the by-laws are strict as to its use, and in London aggregates are confined to Thames gravel, pit gravel, broken stone of a suitable description or similar materials. There is no doubt as to the value of gravel of a suitable nature for foundations, but not always so for other portions of buildings. It was used in its early days for overhead floors until the London Fire Brigade had to caution firemen from entering buildings which possessed this class of floors when a fire was in progress, as they were liable to collapse, and this applies in a minor degree to walls built of gravel concrete.

The by-laws of the London County Council require gravel to be no larger than will pass a three-quarter-inch mesh. Thames gravel has therefore to be screened or crushed. Pit gravel has as a result come considerably into use of late years, this being crushed to the size at the pits, washed, and delivered on jobs ready for use. It has the appearance of being clean, but in many instances, if some is put in a bucket, water added, and stirred for a few seconds, the latter will be found dirty, and totally unfit to use with cement. River gravel from quick running streams is usually clean, but in sluggish ones is often mixed with mud resulting from the washing away of the banks on either side, but this mud is not difficult to get rid of by washing.

Most pit gravel is intermixed with clayey and argillaceous matter, and is totally unfit for concrete unless thoroughly washed, and repeated washings are often necessary before it is usable, which makes it cheaper at times to procure some other aggregate of a cleaner nature.

SLAG.

Slag makes one of the best of aggregates, the only objection to its use being the sulphur which it is said to contain, but this can be eliminated by exposure to the atmosphere and by washing.

It is a waste product. Immense mounds are to be seen adjacent to most iron mines, which have been there for years and have become thoroughly aerated. There is enough slag in various parts of the country to build ten times the number of cottages that will be required after the war.

It is usually considered that all materials that have passed through fire require no washing, but they are coated with a film of fine dust and an impalpable sandy element not apparent to the naked eye, and these are extremely injurious to cement, which combines best with coarse-grained sandy materials, a factor that is well known to those whose occupation is entirely confined to its practical use.

Materials that have pased through a crusher are of the same description. The best way of washing aggregates is described in Chapter IV.

At most iron mines slag is crushed to any size required and sold for concrete work and other purposes.

COKE BREEZE.

Coke breeze was at one time used extensively for floors, and has found more opponents than any other material by reason of the sulphur which it is said to contain, but which can be got rid of in the same way as with slag. It is not one of the best materials for walls owing to its small and uniform size, but has been largely used for suspended or overhead floors. Sir Henry Tanner once said that he had always used it for floors of new post offices and had received no complaints relative thereto. I have used large quantities in the past with good results.

Other objections have been that it will not resist fire or bear a heavy compressive stress. The British Fire Prevention Committee made experiments on actual floors constructed with seven different kinds of aggregates, the result being that coke breeze withstood a fire of three hours' duration with a temperature of 190 deg. Fahr., after which water was played on with a hose and the concrete remained free from cracks or deflection, while Thames ballast proved to be the least fire-resisting of the aggregates tested.

For compression in comparison with brickwork Mr. Kirkaldy tested a brick pier 18 × 18 × 18 inches of stock bricks and blue lias lime mortar and one of a similar size of coke breeze concrete 1—6. The former crushed with a load of forty-seven tons and the latter with 131 tons. But wherever coke breeze is used care should be exercised. Its quality depends largely on the nature of the coal from which it is produced, and it is always advisable to wash it, although in a general way this is but seldom practised. The coke in parts of Scotland is considered by some authorities as a dangerous element in concrete, but I have never found this to be the case, and have used a very large quantity produced in Glasgow.

BOILER ASHES.

Boiler ashes make good concrete, sulphur being the usual objection, but of which in my experience I have never found any evidence. Obviously they should be free from deleterious substances that sometimes get intermixed therewith, such as cotton waste, soot from boiler tubes, etc. Ashes are cleanest when obtained from boiler-houses where mechanical stokers are used and from locomotives. They are sometimes graded ready for use at large works, but if otherwise the grading is an inexpensive operation. Most railway companies deliver them to any of their stations at a low charge, but ashes from locomotives which pass through lias lime districts should be avoided. The drivers often eke out their fuel by throwing in fragments of the stone, which they by some means obtain on their way; these fragments get converted into lime, acquire the same colour as ashes, and are unnoticed, and do not slake at times until the concrete containing them has been completed, when an upheaval takes place and the concrete is entirely ruined. Numerous failures have occurred from this cause. This practice applies to the L. and S.W. Railway, some portions of the Midland, and perhaps to some others. Before using locomotive ashes the source of the supply should be carefully investigated.

DEBRIS FROM OLD BUILDINGS.

Bricks and stone from buildings undergoing demolition make a suitable aggregate for most purposes, provided all mortar and foreign matter of every description is removed as far as practicable. The material should have passed through a crusher and should be thoroughly washed. Old slates and tiles should be avoided. Especial care should be taken that old plaster from the walls, cornices, etc., in which plaster of Paris has been used does not get intermixed with the *débris*, as, no matter what its age, it will, when mixed with cement concrete, cause disintegration, and in floors an upheaval. Concrete of old floors in which plaster of Paris was the matrice, and which had been re-used as an aggregate for new floors, with cement as the matrice, resulted in the concrete having to be entirely removed. Sooty bricks should be avoided, except for foundation concrete, as soot will disfigure all lime plaster and cement surfaces.

BRICK AND TILE WORKS REFUSE AND QUARRY CHIPPINGS.

These make a good aggregate, as a rule, being clean and free from deleterious substances, but require to be crushed to the grade required. Hand breaking will not effect this object. At many large quarries and brick and tile works the materials are crushed to any required size.

FLINTS.

Flints from the chalk formation or picked from the surface of agricultural and pasture land make one of the best aggregates if passed through a crusher, but useless if broken by hand. Their glassy and impermeable nature does not prevent cement from adhering thereto—just the reverse—their superiority in this respect over porous aggregates with rough surfaces having been fully established, although contrary to all theory.

CLINKER.

Clinker, or vitrified boiler residue, does not make a desirable aggregate; it is mostly of a spongy character, unshapable, and requires a good deal of washing to rid it of its fine dusty constituents.

BURNT CLAY.

Clay, if properly burnt, is of the nature of bricks, and forms a fairly good aggregate; but it requires the services of a practised man to supervise the burning, otherwise it varies in its degrees of hardness. The cost of fuel and labour is considerable, and as a result it is seldom used if any other aggregate is available.

CHALK.

Chalk from the middle and lower chalk formation is usually as hard as some quarry stones, and makes a good aggregate, but is seldom available. The upper stratum, being of a soft character, is not desirable, but where no other aggregate was to be had on one occasion, about thirty years ago, I used this material as the aggregate for concrete walls and overhead floors of a pair of cottages. The finer portion, which passed through a quarter-inch mesh, was eliminated, and boiler ashes and sand of a similar grade substituted. These cottages have always been weatherproof, and internally the walls are quite dry.

II.

MATRICES.

LIME.

LIME appears to have been the only matrice, so far as we know, used by the ancients, and of a hydraulic character. The name "hydraulic" is given to limes which set and harden equally as well (or better) in water as in air, and non-hydraulic when of an opposite character.

Remains of lime concrete have been found in Egypt long anterior to its known use by the Romans, who are supposed to have introduced it into this country. The invention of Portland cement caused lime for concrete to be abandoned to a great extent.

Lime made from the upper strata of the chalk formation is unsuitable for concrete, being non-hydraulic and deficient in strength; but the middle and lower strata are to a certain extent hydraulic and stronger, and known as grey stone lime. The lias stones make the best lime, and are to be found in many parts of Great Britain, but they are slow in slaking when water is added to reduce them to a powder. As a result they have to be ground for concrete purposes, and even then small, unground portions are sometimes in evidence, to remedy which it should be kept in a waterproof shed in bulk on a wood floor, occasionally stirred to allow air to permeate, and the doors kept open as much as possible. This is called air slaking, and the time allowed for the purpose two to four weeks, depending on the amount of humidity in the atmosphere. Smeaton, the engineer of the Eddystone Lighthouse, found that it lost no strength when kept in airtight casks for seven years. Lime reduced to a powder in this way is called hydrated lime. An advantage possessed by lime is that its greatest strength is when mixed with two to three parts of sand, whereas Portland cement diminishes *pro rata* to the amount of added sand.

On one occasion, when cement was a high price, I erected some buildings of a plain character in which a thousand cubic yards of concrete were required for the walls. I used as a matrice one part of cement and six parts of ground lime by measure, and twenty-one parts of an aggregate composed of crushed *débris* from old buildings that occupied the site. The result was quite satisfactory, and, although not reinforced, the walls are as good at the present time as when built, twenty-five years since, and no temperature or other cracks have developed. As lime is only about one-half the price of cement and half the weight, it is a question whether, under special circumstances, it could not be employed at times to advantage.

SELENITIC CEMENT.

Selenitic cement, the invention of General Scott in 1870, consists of lime to which about 5 per cent. of plaster of Paris is added. It is inferior in strength to Portland cement, and not in much request as a matrice.

ROMAN CEMENT.

Roman cement sets too quickly, and deteriorates by keeping, and is only useful for special purposes.

PLASTER OF PARIS.

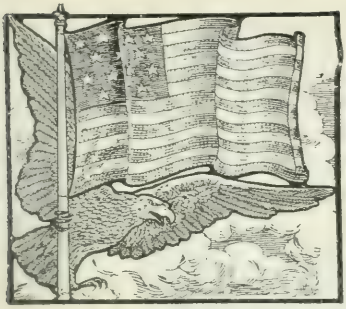
Plaster of Paris was used extensively for overhead floors previous to the invention of Portland cement and for some time after. It expands considerably in setting, which necessitates for floors the use of wood fillets at intervals, which are withdrawn as soon as it commences to swell. It causes iron with which it comes in contact to rust, loses its strength by keeping, and is much weaker than Portland cement.

PORTLAND CEMENT.

Portland cement possesses properties that are essential in a good matrice. It is of great strength, hydraulic, and affords sufficient time when mixed with the aggregate, and before it sets, to deposit it where required. It was the practice at one time to allow it to aerate in a similar way to that described for lime, but it is now ground so fine that manufacturers say it requires no seasoning, but is better for use on delivery, and that it loses some portion of its strength if kept long and not confined in sacks or casks. The quality of cement—a very important feature—is difficult to ascertain from appearance or by handling, and only by making proper test specimens can reliable results be obtained. This will necessitate the use of a testing machine, and even then the results will only indicate the quality in a certain direction, and, if complete tests are to be made, the use of a laboratory is necessary.,

Unless the work is of an extensive character and ample time is allowed for testing, which is rarely the case, it had better not be attempted except by an expert, who would be certain to obtain more accurate results. If a guarantee is given that the cement is to the British Standard Specification, but little doubt can exist as to its quality. This specification decides the various points that it is agreed are necessary to ensure the best quality, and reputable manufacturers guarantee their cement to be of this standard and test it at their works

(To be continued.)



CONCRETE IN SEA WATER.

By R. J. WIG and L. R. FERGUSON.

The question of the behaviour of concrete in sea water is one of the greatest importance, and the result of some most interesting and instructive examinations of such concrete structures has recently been published in "Engineering News Record," in the form of five articles of which we reprint the first herewith. The investigations were carried out by Messrs. R. J. Wig (Bureau of Standards, U.S.A.) and L. R. Ferguson of the Portland Cement Association. The investigations extended over a period of two years, during which 146 different structures in the United States alone were examined. The authors, in the course of this article, state:—"It is not the intention to demonstrate that concrete cannot be used for marine structures. On the contrary it is their opinion that it is a most economical material, if it is made so as to successfully resist sea water action, and it is their opinion that it can be made so."—ED.

THE durability of concrete in sea water has been a subject of absorbing interest to engineers for many years. Numerous isolated structures have been examined and many theories have been advanced, but it is safe to say that there is no unanimity of opinion among engineers as to the condition of marine concrete or as to the causes of deterioration, if such deterioration is admitted.

It has been the privilege of the writers in the past two years to make a personal examination of nearly every concrete structure in sea water in the continental limits of the United States, besides a great number in Canada, Cuba, and Panama. In addition, detailed information has been secured through American consular offices on the methods of construction and present condition of concrete works in various harbours all over the world. As a result of this study the writers are convinced that they have secured data which warrant conclusions of great importance to the engineering profession. In many cases the conclusions drawn are at variance with common engineering practice, which is shown to be incorrect by the comprehensive evidence at hand, and some radical changes in design and methods of construction are suggested. These conclusions account for the almost universal progressive decomposition of concrete in sea water and lead to suggestions for the improvement of concrete making and placing, which should insure the permanency of a material that otherwise is so well suited for many needed ocean structures.

It is the intention to outline some of the studies made, and these articles will demonstrate that (1) permanency for plain and reinforced concrete can be obtained under most, but not all, conditions of exposure; (2) all concrete in sea water, both in northern and southern climates, is subject to chemical disintegration under certain conditions; (3) *reinforced* concrete of excellent quality, designed according to recommendations of engineering societies and present practice, is subject to relatively rapid deterioration in most localities; (4) the materials and methods used in construction have an important bearing on the durability of concrete and the design and the protection provided influence greatly the permanency of the structure.

The fact that the number of structures examined has been so large is of much importance. Any investigation which is confined to a limited section of the country would lead one to draw very erroneous conclusions if deductions of a general character were attempted. Such general deductions can only be made after a survey of broad scope covering sections where widely varying climatic and physical conditions exist.

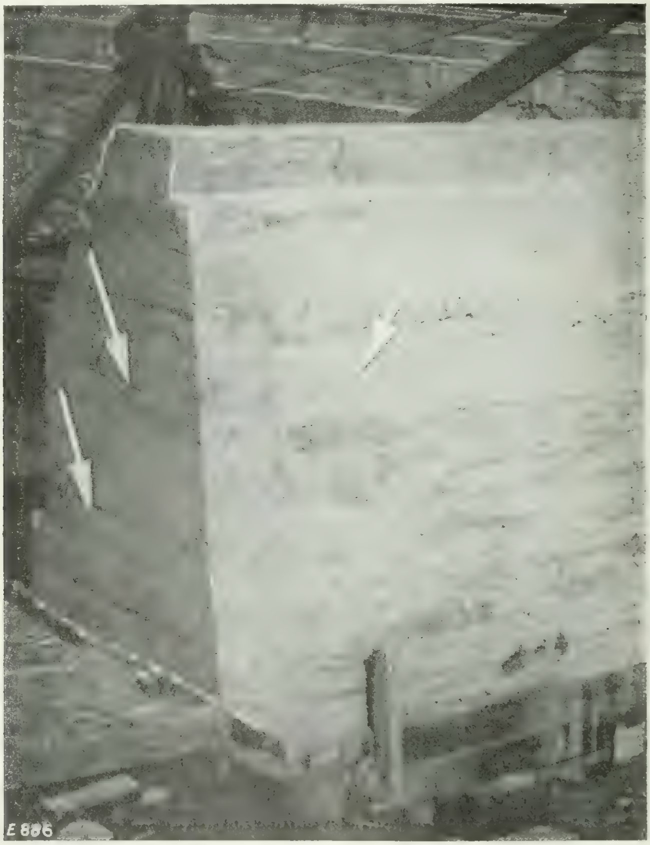


Fig. 1. Arrows indicate Construction Seams in wall immediately after construction.
Concrete in Sea Water.

In addition to this, the facts must be known about the methods used in construction, the materials of which the concrete was made, the amount of water used in mixing, the past and present conditions of exposure, the salt content of the water, and in fact all the details which can only be secured by a careful examination of the structure, by studying the specifications, drawings, records and photographs made during construction, and by interviewing those actually in charge of the work.

This information was secured by the writers in conformity with a detailed questionnaire, and the data thus obtained frequently offered the true explanation of existing conditions. Without this detailed knowledge entirely wrong conclusions might easily have been drawn, and in fact this was found to be the case in a number of instances. Of course, it is often difficult to unearth the actual facts about the building of a structure ten or fifteen years old; unless these facts appear in the records or can be seen from a progress photograph they must be secured from the engineers and inspectors who had charge of the work. If any defects are now in evidence or if the concrete is deteriorating these men feel a sense of responsibility and sometimes are loath to tell what actually happened during the construction. The conditions under which the present investigation was made were extremely fortunate, for to the greatest possible extent were all the facts made available.

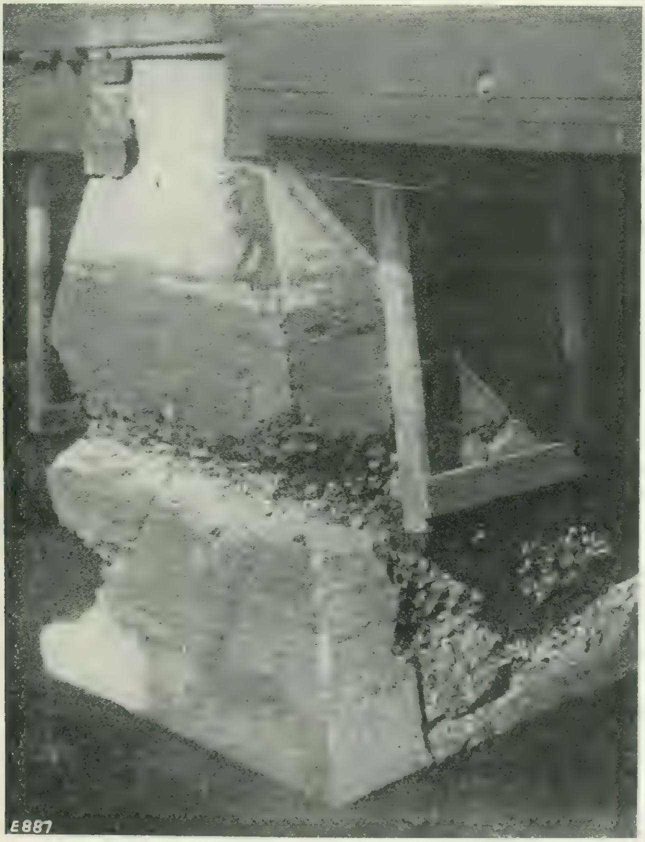


Fig. 2. View showing how Construction Seams were attacked by sea water in 12 years.
CONCRETE IN SEA WATER

One or two examples of the utility of historical references may be cited. The illustration (*Fig.* 2) shows a concrete wall in a state of progressive disintegration. If one were to examine that wall in the light of present information there might be some difficulty in understanding or analysing the reasons for the partial failure. However, an examination of the view (*Fig.* 1), which is of that wall twelve years before, throws great light on the trouble. It will be noticed in the early view that construction seams were formed, as indicated by the arrows. The wall was built dry within a cofferdam, and although perfectly obvious the seams do not look particularly dangerous. A study of the later picture, however, shows that the deep erosion of the sea water has taken place right along these construction seams.

There is a concrete pier along the New England coast which has been the subject of a number of investigations and reports. This pier was built about fifteen years ago, and even before it was completed there were signs of deterioration. This continued, and before a great while endangered the stability of some parts of the structure. From the construction photographs and the evidence of the inspector in charge of the work it was clear the concrete was mixed dry. In another case an inspector testified to the fact that a tremie had not been used in its normal and expected fashion, but as a chute, permitting the concrete to settle from its bottom through 8 ft. of water.

It is not the intention of these articles to demonstrate that concrete cannot be used for marine structures. On the contrary, it is the opinion of the authors that it is a most economical material to be used if it is made so as to successfully resist sea-water action, and it is their opinion that it can be made so. The articles will, however, illustrate in an emphatic manner the rapid deterioration which results from the use of too little or too much water in mixing concrete, the origin and development of deterioration from normal construction seams which are common to most concrete work, the protecting influence of adequate fender systems or granite facings, the need for radical modification in the design of reinforced-concrete marine structures, and the conditions under which sea water can be used in mixing the concrete without detrimental effect.

It is a fact that plain concrete, if exposed to physical abrasion, will very soon commence to disintegrate, due to chemical action. The evidence collected by the authors shows that reinforced concrete will, in practically any climate, begin in a short time to fail above sea water due to the absorption of the sea water or penetration of sea air bearing chlorine to the reinforcement. This reinforcement soon rusts and the concrete cracks.

Engineers recognise that deterioration of unreinforced concrete takes place in certain localities, but the opinion is held by many that the trouble is confined to the north, where freezing conditions exist. Such is not the case. Both chemical and physical disintegration of concrete structures are in progress along all our sea coasts, although the action is greatly accelerated in the case of plain concrete where low temperatures exist and in the case of reinforced concrete where high temperatures exist.

In pointing out the conditions which have led to deterioration in some of the concrete structures there is no intention to criticise those who were in charge of design and construction, for most of it accorded with current engineering principles. The only reason for calling attention to the causes for deterioration is to show how such trouble can be obviated in the future and more durable structures built of concrete.

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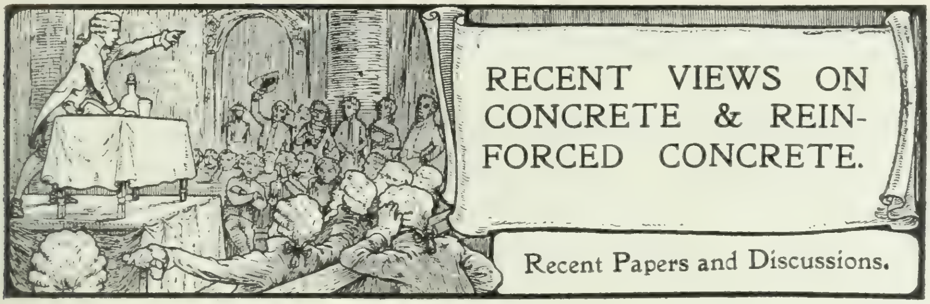

RECENT VIEWS ON CONCRETE & REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE CONCRETE INSTITUTE.

BRITISH TRADE AND THE METRIC SYSTEM.

By E. A. W. PHILLIPS, M.Inst.C.E., M.C.I.

The following is an abstract from a paper read before the Concrete Institute on January 24th. A report of the discussion is also given.

THE above title has been assumed for this paper because it is the title of a book[*] on the same subject and because it is very appropriate, since the author's object is the increased commercial prosperity of the Empire.

It is argued that the book introduces a new metre and a new system, with disadvantages which hardly need mentioning; that the new metre is a "freak" metre; that it would not appeal to our present metric customers; that the simplification of the British system is merely collateral to the advantage the metric system would give us in the other markets of the world; and that the public generally could never be induced to adopt a new decimal standard. The author quotes all this with a view to showing that he is acquainted with metric arguments. He has indeed been so since long before 1908, the year of the discovery of the Tripod, so that the first thing he wishes to impress upon his audience is the fact that he did not open his offensive without a full knowledge of the entrenchments he means to take.

Although what he has to say is of supreme importance to British trade throughout the Empire, it ought not to be assumed that he is acquainted with every trade custom and exigency. He offers trade a sure tool, which he is aware, from the investigations he has been able to make, is as good, at least, as any other article on the market for certain special purposes, and infinitely superior for common everyday use.

The point is that the Tripod is nothing new. The British already have it ready to hand. So far from adopting any new system, they have only to take the perfectly serviceable tools they possess from the national tool-chest and use them properly.

The term "British trade" in the title is to be taken in its widest possible sense as including every human transaction in the Empire which can, by any stretch of imagination, be regarded as "sale" or "barter."

If some catastrophe removed all that appertained to weights, measures, and currency from this planet, not the standards only, but *everything*, how would mankind set about their renewal? That is a question which should not be overlooked in any argument, because one answer undeniably might refer to democracy and its obligations. No solution which did not as carefully provide for the needs of the small men as those of the great men ought to stand any chance of acceptance. Can any modern civilised man assert the contrary? It may be assumed, therefore, that an international system of weights and measures ought to serve all men, not a minority, however important, not even a majority.

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[*] "British Trade and the Metric System," by E. A. W. Phillips, M.Inst.C.E., M.C.I.

Another important consideration, the outcome indeed of the last paragraph, is contained in the question: Should a system of weights and measures be purely decimal or should it afford an opening for the employment also of vulgar fractions, and if so, to what extent? This is not merely a matter of opinion; the answer ought to embody personal experience. If even 80 per cent. of men could do with occasional halves, quarters, and eighths, and the system failed to provide for the needs of the remaining 20 per cent., who required sixteenths, and perhaps even smaller non-decimal sub-divisions, the system would be defective, and involve serious hardship.

It is impossible to say exactly how the ancient scheme came to be framed on the lines on which the author discovered it, but the theory of the Tripod or triple scale in weights and measures is this:—

(*a*) The Polar Axis, about which the whole globe revolves, ought to be the selected earth-line upon which an international scheme should be based.

(*b*) The inch, the most important unit in the whole system, ought to be the 1/1,000,000,000th part of the double Polar Axis, or the 1/500,000,000th part of the single Polar Axis.

(*c*) The chain ought to be 792 of these inches, the number 792 being the least common multiple of all numerals from 2 to 12, with the exception only of 5 and 10, the decimal numbers provided for in the decimal scale, and 7, the sacred number, little used, and then chiefly to multiply.

(*d*) The numbers representing the decimal, fractional, and duodecimal scales, which would cover all human needs, are 10, 11, and 12.

(*e*) Divide the chain into 10, 11, and 12 parts, and we obtain the double metre, the double yard, and the double duodecimal unit. The metre, the yard, and the duodecimal unit are each the base of a decimal scale, a *système usuel,* and a duodecimal scale respectively.

That is the theory as it presented itself after months of patient digging to the author, and the strangest thing about it is the extraordinary way in which the British system of weights and measures moulds itself into perfect shape round the skeleton.

The author here quoted a number of instances from our weights and measures in support of the above theory, specially referring to the Belgic yard, which, he said, had been in existence in Britain since the third century at least. Five of these yards made the rod, pole, or perch, and four rods (as now) the chain.

The Belgic yard was therefore the Anglo-Saxon metre, and it appears to have been divided both decimally and into three Belgic feet and 36 Belgic inches. There was, at the same time, a true yard of 36 English inches, and 39·60 English inches seem to have made the Belgic yard. It should be noted that the subdivision of the metre into three metric feet and 36 metric inches is Napoleon's *système usuel,* introduced into France in 1812 and abolished in 1837.

We still employ the Belgic yard in the rod, pole, or perch of 5, the chain of 20, and the furlong of 200 metres (British), and in square measure in the rod of 25, the rood of 1,000, and the acre of 4,000 square metres (British). And it will be found that every British unit is derived, more or less directly, from the Belgic yard, which appears indeed to have been the common metre of Europe up to the fifteenth century, so far as can be made out from the records.

We have a metric ton, in the common British ton of 2,240 lbs., of the weight of a cubic Belgic yard of water, at or very near the maximum density.

Attention is invited to the strange resemblance between the two systems:—

Ancient British: Metre, 39·6 in.; chain, 20 metres; ton, cubic metre.
French: Metre, 39·37 in.; chain, 20 metres; ton, cubic metre.
(of water at or near maximum density.)

That a separate duodecimal scale has long been known in the East is proved by the existence of the gudge of 33 in. and its 144th part, the jow, in India.

It is interesting to note that a gudge of 33 in., divided duodecimally, gives us a unit of 12 avoirdupois ounces, and finally a carat of 3·04 grains, and a lower weight indistinguishable in practice from ¼ grain. Compare our troy weight as a vestige of the duodecimal scale in Britain.

The Decimal Association originally took the hand as a symbol of the decimal system. It may also be regarded as a symbol of the perfect system, the 4, 8, and 16 "fingers," the 5, 10, and 20 fingers and thumbs, and including the wrists, 6, 12, and 24, representing the fractional, the decimal, and the duodecimal scales. The illustration will not appear puerile to those who are acquainted with the part the hand plays in Hindoo mysticism and elsewhere.

The universal prevalence of the following units all through the world is very remarkable:—Measures approximating to a half-metre, a foot, and a bushel; and a weight approximating to a pound. Surely this is more than a coincidence?

The fact that the foot is sometimes the third of a metre and at other times nearly the English foot is the more remarkable when Napoleon's *système usuel* is remembered.

The well-known human necessity for being able to work in complete tens, in fractions, and again in complete twelves, would, perhaps, account for a set of three scales in any other science than that of weights and measures, and be accepted as sufficient proof of the Tripod.

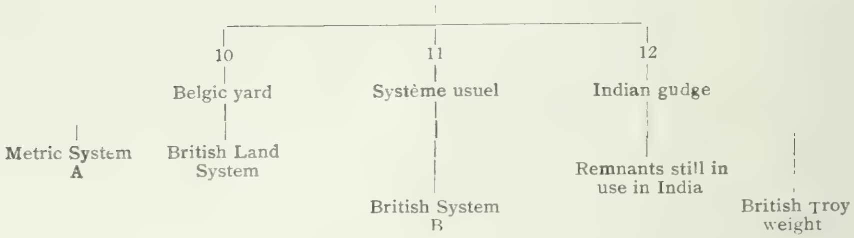
Why should the Decimal Association complain of the "distracting jumble" in British weights and measures but for an instinctive feeling that our weights and measures should be employed with method? We can see very easily now what has happened. The British are making their *système usuel* do the work of all three scales, and are, besides, mixing up different tables and also decimals with fractions. Rods, instead of being dealt with as 5 metres, are reduced to 16½ ft.; bushels are defined in pounds-weight; troy-weight is occasionally mixed up with avoirdupois, feet and inches with links; while we have at least three different tons in common use. In the cotton trade prices are given in pounds-weight and decimals of a penny, when sacks (the tenth of a ton) and florins (the tenth of a pound-sterling) are obviously the best units, from a wholesale weights and measures point of view, for the purpose. This particular abuse has crept in through the American ton and the cent, and no doubt there is a similar reason for every abuse if its history could be ascertained.

As a coincidence of importance, taken in connection with the above remarks, please note the anxious care bestowed upon the purity of metric units, in correct decimal relationship, in France. The metric system would break down in a decade if subjected to the abuses put upon the British system, which has only survived through its superior general fitness and more satisfactory units. "It is usual for building surveyors to measure brickwork by the rod and convert into feet, thus giving themselves unnecessary trouble," says Colonel Sir C. M. Watson in his book. A rod is 5 metres square—that is, 198 in. by 198 in. The Royal Institute of British Architects lays down for brickwork four courses of brick and four joints to a foot, a very inconvenient figure—66 complete courses to a rod of height. Joints in brickwork are very thin, and might be made wider with advantage. Why not, employing bricks of the present dimensions, run 60 courses to the rod of height and 20½ stretchers and joints to the rod of length? The quotients are 3·3 and 9·66 in. respectively, as against 3 and 9·25 in. now. The regulations at present are not labour-saving (see Molesworth's Pocket Book, 26th Edition, pages 90 to 96). The rod is a convenient unit and the men understand it. The trouble lies in the mixing up of two sets of scales which are incompatible. The recognition of the British metre would reconcile all difficulties. There should be a builder's rule in use on every work—a flat rule, 39·6 in. long, divided into 100ths on one face and into inches and 16ths on the other face.

It seems to the author that the difference between the French and British metres represents just the unbridgeable gulf between capital and labour in this country to-day. You cannot stretch 39·37 to 39·60. Both sides must adopt a common metre, and since the educated classes suffer least by a change of this kind, the selected metre should in this country and Empire be the British metre.

The author hopes that in the above he has proved the existence of the tripod in British weights and measures, and that there is very good reason for considering them in the new light. The present position is best explained by diagram:—

TRIPOD.



The two practical systems to-day, A and B, are locked in deadly conflict, which in the light of the tripod appears uncommonly like aggression on the part of A. If A wins, it means the victory of decimal over vulgar fractions, to the permanent inconvenience and hurt of many millions of human beings. If B won, however, nobody would be hurt, because decimalists would still be free to employ decimals, and might legally employ the British land system and corresponding decimal weights and measures for a great many vital purposes. They would not be prevented from employing decimals in the *système usuel.*

The British seem to have retained the correct international metre, having departed very little from the true length. But there is little doubt that both French and British systems, and their *systèmes usuels*, are derived directly from the ancient Tripod. The question now is how to reconcile metre and yard in an "*Entente cordiale.*"

As definite points to place before the meeting the author asks :—

(*a*) Is it possible to restrict the use of the metric system as an international standard for pure science?

(*b*) Is it possible to make the British decimal system (as shown in the preceding paper) the international standard for trade, commerce, and engineering—that is, for applied science?

(*c*) Ought not the British *système usuel* be permitted, by international agreement, respectful treatment by other nations, to be legally used as desired in any foreign country, even a metric country, by arrangement between contracting parties? This seems to be bare reciprocity in return for the legal recognition of the metric system in the British Empire.

(*d*) The question of an international currency is outside the range of practical politics at present. But it may be remarked that, with the introduction of a metre of 39·6 in. in trade, commerce, and engineering, there is no reason why there should not be *one* coin (of about the value of two shillings in every country) of standard and equal weight and fineness, to be minted and used in every nation, even if it is not internationally current.

DISCUSSION.

The President said Mr. Phillips was an enthusiast on the subject of British weights and measures. He had suggested that they should confine their discussion to throwing fresh light on the British Tripod system, and leaving the French metric system out of the question altogether, but he did not know whether they all wanted to do that; perhaps it would be their pleasure to hear something of the other side.

Mr. Ewart S. Andrews, B.Sc., remarked that the argument put forward in the Paper had not convinced him in the least that the metric system or the decimal system was not in every respect preferable to the system which they had in this country. The victory of the vulgar fraction system over the decimal system would be to the permanent inconvenience of many millions of human beings and therefore he was strongly opposed to it becoming universal. The whole reason why they found it difficult to appreciate the decimal system in this country was that they had inherited generations of upbringing on the fractional. That was the principal cause of the difficulty, and he believed it was one of the great causes why people like himself, to whom had been entrusted the difficult task of educating engineers, found that engineering students were very often backward in calculations and in mathematical reasoning. Most English people, even if they understood decimals, did not think in them, and the beating of the democratic drum which they found so strong in the Paper was merely an attempt to hide their heads in a sack. As an optimist, it seemed to him a hopeless policy that because generations had wallowed in ignorance they were to follow in their steps. They ought to benefit by the wisdom of the ancients, but they ought not slavishly to follow their errors, and he was absolutely convinced that the decimal system was the one upon which the greatest national efficiency could be based. He had no objection to the adoption of the metric system ; he was not keenly in favour of it, but it was in use over a very fair area of the world, and he thought it would be very well if they gradually educated themselves into its use. He wanted to try and nail to the mast the idea that they must have a system which should be based upon it.

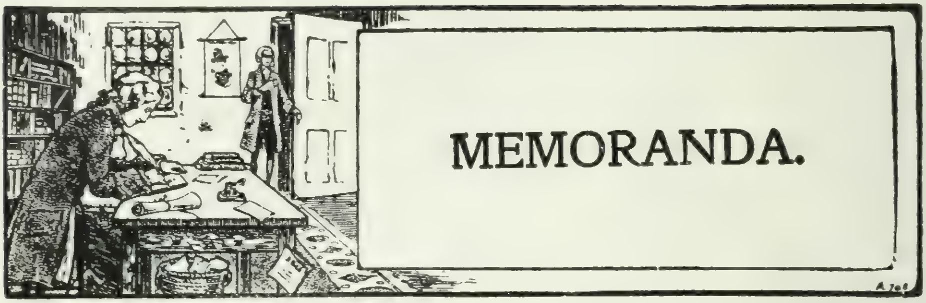
Mr. George Moores, F.S.S. (Secretary of the British Weights and Measures Association, and representing the American Institute of Weights and Measures), confessed that at one time he was a decimal man and lectured in favour of the decimal system and of the metric system, but after travelling a great deal in America and Continental countries he became convinced that the English and American system was preferable for general engineering purposes and for general manufacturing purposes. Why did they go on turning out the best engineers, why had England the greatest export trade in the world, and kept on increasing it faster than any other country, and why did they keep abreast of all the improvements and all the progress that other nations were making? The answer was simply that there was something in the British weights and measures which was not perhaps obvious, but was found out by the man when he began to do things. They must have in this country that system which would enable them to do work of the highest possible character at the least possible expense and in the least possible time. They did not object to the use of decimals where decimals were better than any other kind of fractions for calculating by, but they objected to being tied down to the use of decimals when other divisions suited the purpose in hand better.

Mr. W. A. Green, M.A., B.Sc., was not convinced that they should be better as tripod creatures. Standardisation was a very valuable thing, and if they could get a universal standard in measures it would undoubtedly be very excellent. The question was what standard could they adopt. Mr. Phillips would like them to adopt his tripod standard. He did not think they would get any forwarder by it. It was far too complicated. As Britishers they ought to be able to tackle anything, and, if they were to have a standard, do not let them say that they were unable to adopt other standards; it was highly improbable that other people would adopt their standards.

Mr. B. McLean Gibson, as a North Country engineer who had met quite a number of junior technical students, said his experience was that the boys of 14 attending secondary and technical schools not only understood decimals thoroughly, but, he might almost say, thought in logarithms. They immediately turned things into logs if they wanted a square root of anything, and he should say they were quite capable of doing anything in a mathematical manner.

Mr. H. Kempton Dyson remarked that there were two systems in vogue by which most of the trade of the world was done, namely, the metric, which was the Continental system, and the British, which was adopted by Great Britain, her colonies, and America. It was true that the greater part of the work was done by Great Britain and America, and therefore it might be argued that, instead of advocating that we should adopt the Continental system, they should adopt the British, but it would not be quite a practical thing to suggest that. He thought the practical thing was to do what Mr. Phillips had done, so that by only adding one unit to their system they could find a *via media* to reconcile the Continental with our own.

Mr. Phillips, in replying, said the great point of his theory was that it showed them how they could serve the interests of every man which decimals did not do. With decimal fractions they were trying to force everybody, which he said was wrong, wicked, and not democratic. True democracy was to give every man his chance. The only reason why they had gone mad over decimals was because they could write them in two ways, and they looked so astonishingly clever. They were not clever; they were just vulgar fractions and no more. If they wanted to do the right thing by humanity, they had to provide a system which would suit all men. If they did not do that it was an utter failure and would lead to a fresh war by and by.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Institution of Civil Engineers.—On January 2nd the Institution of Civil Engineers completed the hundredth year of its existence, having been established in 1818 at a meeting of eight engineers at the Kendal Coffee House in Fleet Street. A statement commemorative of the founding of the Institution on January 2nd, 1818, was made, present conditions precluding more formal celebration of the centenary.

The Council of the Institution of Civil Engineers have resolved that its examination in engineering drawing, bills of quantities and elementary knowledge of specifications, which is at present an optional subject, shall be, after January 1st, 1919, obligatory for all candidates for Associate Membership. The examination is intended to be a suitable test of the knowledge and skill which should be acquired during the requisite training in engineering offices, and will apply to the several main departments of practice. The tests in drawing and quantities may be conducted in part by means of the production of drawings and quantities which have been prepared by candidates under their employers and teachers. Students of the institution may be allowed to take the examination prior to the time at which they become candidates for election as Associate Members.

Tunnel Work in Buenos Aires.—At a recent meeting of the Institution of Civil Engineers Mr. W. L. Brown, who acted as the engineer for the Buenos Aires Western Railway Co., read an interesting paper regarding two tunnels built under the City of Buenos Aires for the above-named company.

The works consist of a concrete-lined, single-track tunnel, three miles long, running under the central part of the city and giving the railway company a direct connection for goods traffic only between their main line and the port; and of a concrete-lined, double-track tunnel about two-thirds of a mile in length, which leaves the main line just outside the terminal station, and brings suburban passengers to a joint underground interchange station, where by simply walking across the platform they can join the tramway company's underground cars running into the heart of the city.

The goods tunnel leaves the main line on the north side about one kilometre outside the terminus. The ruling gradient opposed to the heavy traffic to the port is 1 in 62, equivalent to about 1 in 55 when allowance is made for the curve of $17\frac{1}{2}$ chains radius. This gradient was the best possible under the conditions and is barely a train-length; otherwise the steepest gradient opposed to heavy traffic is 1 in 100. In the opposite direction the ruling gradient is 1 in 67, equivalent to about 1 in 60 if allowance be made for the 20 chains' radius curve.

The design adopted for the goods tunnel is a horseshoe-shaped mass-concrete lining, 1 ft. 8 in. thick, large enough to accommodate the standard Argentine broad-gauge (5 ft. 6 in.) railway, the construction gauge of which is 15 ft. 10 in. high and 13ft. 9 in. wide. A cast-iron lining was considered, but was rejected on account of cost. The design for the passenger tunnel was also a mass-concrete lining.

The subsoil through which the tunnels have been constructed is almost ideal for tunnelling operations; it is easy to "get," will stand untimbered almost indefinitely without showing any signs of movement, and will not disintegrate even on the surface, if not exposed to the weather. The earth, called *tierra pampeana,* somewhat resembles a clayey marl, but does not appear to have any of the treacherous qualities of clay or marl. In fact, it is more like a soft rock than anything else. It is customary to excavate for a depth of 25 ft. or more with a vertical face immediately alongside existing buildings, and although the buildings themselves are usually supported by some very light shoring, the excavation itself is timbered only in exceptional circumstances. In constructing sewers, also, it is a common practice to dig a narrow trench to about the level of the sewer and then to widen out, and this without using any timbering. The only point where ground of a different nature was found was under the gardens near the port, where there was a length of about 650 ft. of made ground, consisting of mud dredged from the river at the time the docks were built. This is of very unstable nature, but when the work was started there was no idea that any structure would have to be built at that point, and it was only when the railway company were obliged to cover in the approach there, instead of building the line on the surface, that difficulties with this ground had to be considered. The covered-way section was, for the greater part of its length, built on a floating foundation. It consists of a heavy concrete invert supporting two vertical brick walls and covered by a roof consisting of steel beams and concrete jack arches. It was originally intended to continue the floating foundation to the tunnel mouth, where the filling ends with a retaining wall about 20 ft. high, and to ensure the stability at the outer end of the fill by confining the made ground within sheet piling; but, as the material at that point proved considerably softer than the trial piles had indicated, it was decided to carry about 41 yards of the covered way and the whole of the retaining wall on reinforced concrete piles driven down to the solid ground below. A slip joint was left in the walls, between the section carried on piles and that with a floating foundation, to allow for settlement in the latter. The settlement was rather greater than was expected, and continued for about ten months, the average amount being about two inches.—*Times Engineering Supplement.*

Concrete for Churches.—An interesting example of concrete in this connection is to be found in the Cathedral of Tunis, which was recently completed, by putting on two high belfries in reinforced concrete.

Building-Stone Testing.—The United States Bureau of Standards has installed an ingenious form of apparatus to test the effects of freezing and thawing upon building stones. It is well known that all kinds of stone, slate, brick, concrete, etc., will disintegrate in time when exposed to the action of frost, especially in humid climates like that of the Eastern United States. This action is due to the freezing and subsequent expansion of the water held in the pores of the material. As it is very desirable to ascertain the merits of different building materials as regards their susceptibility to such damage, many tests have been made with this object in view. The apparatus installed by the Bureau is of its own design and is very rapid in operation. A charge of stone, concrete, or other material will be automatically moved back and forth from a freezing chamber to a thawing one at the intervals required to congeal the contained moisture completely and thaw it, and it is expected that 80 to 100 freezings will be made in a single day, as compared with the period of several weeks formerly required. It will thus be possible to determine definitely the number of freezings required to produce any desired degree of disintegration, and with this information to predict the approximate length of service a given grade and kind of material will give in a specified locality.—*Times.*

Chalk Concrete.—We give below some interesting notes as to the use of chalk as an aggregate. This material is not generally advocated, as in the opinion of many it is apt to weather badly, especially when obtained from some formations. Special care is required in its selection and execution. The work here described, however, appears to indicate that chalk as an aggregate has some possibilities for farm work.

The illustrations are of an old implement shed, which had the merit of possessing a moderately good roof when war broke out. The decaying posts supporting the roof were replaced with stout chestnut poles from the adjoining woods. All that was necessary then to convert this implement shed into a shed for twenty cows was a good front and floor. The front was successfully, if roughly, formed of chalk concrete half way up, finishing up with weatherboard and sashes, as illustrated.

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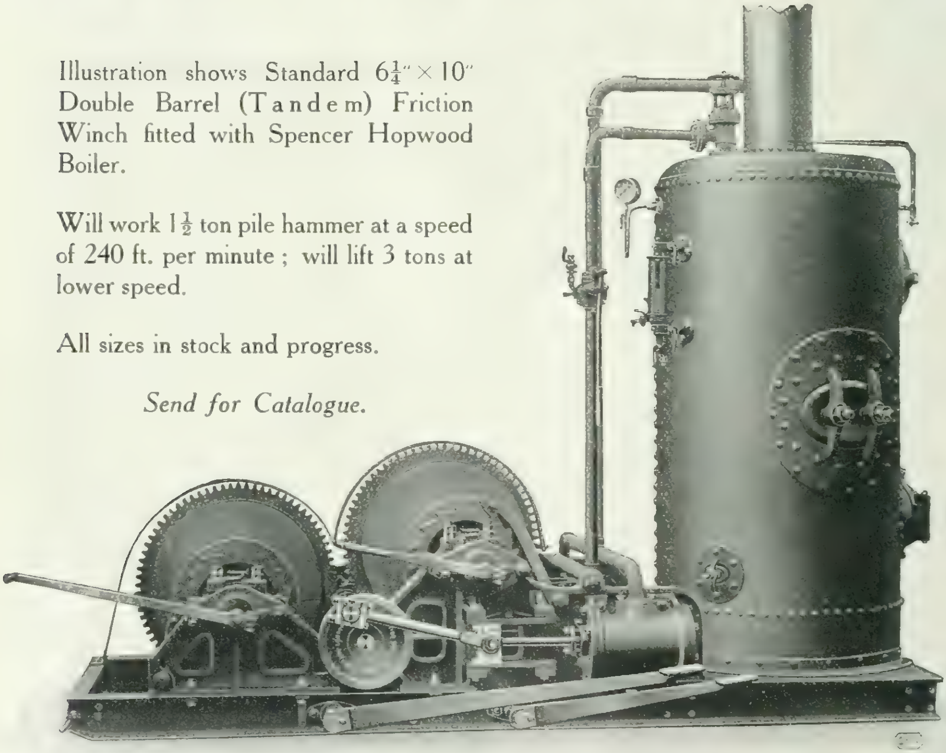


DOCK HOUSE, *Billiter Street*, LONDON, E.C.

Continuous mangers were cast on to the inside of the wall over a collapsible mould forming about three-fifths of a circle. All the chalk concrete inside was fined over with sharp sand, but the outside seemed fairly satisfactory, so this was left (apart from a little pointing) unfaced as an experiment. The forefeet of the cows stand on rammed chalk, but the hind feet stand on a shelf of chalk concrete with a deep sloping gutter behind.

There is the usual raised gangway behind the cows, the whole floor being faced over with sharp sand and cement.

A dairy was formed in the north side of the bank, the floor walls and roof being of this material, the concrete on the latter acting as a cover to curved corrugated sheets resting on tee irons, while sundry shed walls have been erected with iron stanchions to carry rails and boarding for the upper part.

Chalk cement takes a long while "to go off," so frost catches work that is not properly protected if it is cast too late in the year. Once it is properly dry frost does not seem to effect even the exposed nodules of chalk.

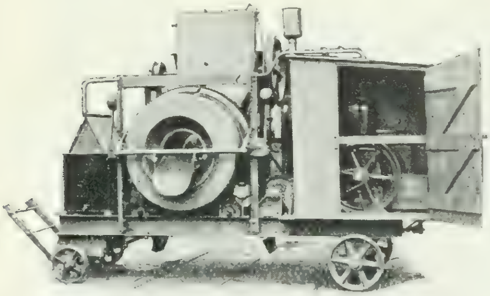
A grains pit is shown beyond the cowshed in one illustration.

We are indebted to Mr. W. Cobbett Barker, of Rochester, for our illustrations and the description of same.

House Numbers Moulded in Concrete Blocks.—A novel way of indicating house numbers has been adopted in Pasadena, California. Concrete blocks are utilised in which the numbers are moulded. These are set out on the edge of the curb, so that he who runs (in an automobile) may read without getting out of his car and walking up to the house to find out whether it is the place he is looking for or not. The blocks are only 4 in. by 7 in. face surface, with triangular sides that slope back from the street.

Concrete Stone Festoons.—In *Concrete*, U.S.A., Mr. R. F. Havlik writes as follows:—

"The use of concrete festoons on buildings is new. In almost all instances when anything of the kind is wanted it is carved out of a block of stone, the block being larger than the ornament. In this case, however, the stone was made the same size as the ornament, so that nothing but the ornament shows. The stone is set into the brickwork, the brickwork being fitted to the ornament. Festoons of concrete have been used on a large hotel in Chicago."



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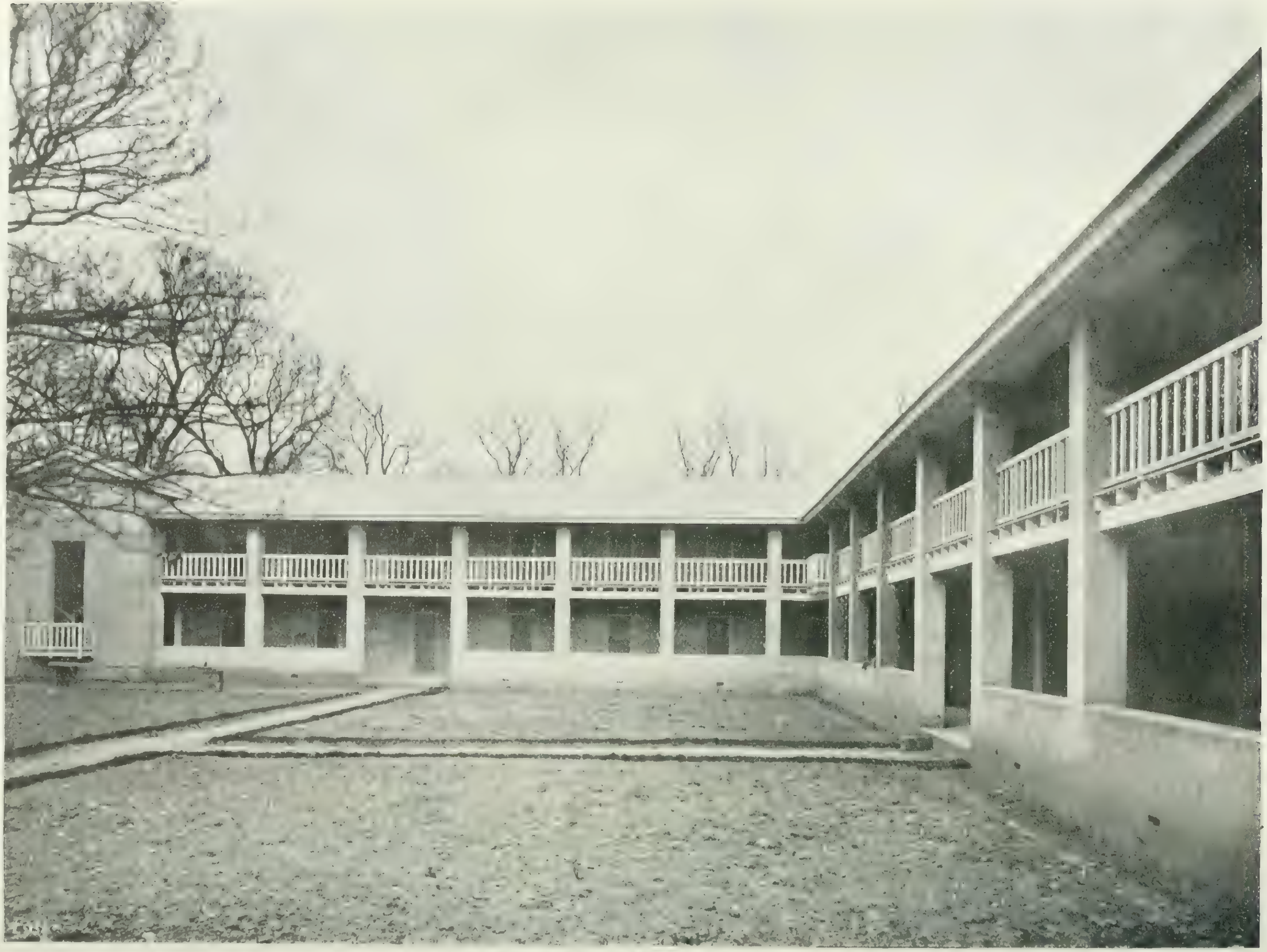

Some Recent Concrete Block Buildings.

(*See page* 115.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIII., No. 3. LONDON, MARCH, 1918.

EDITORIAL NOTES.

THE FUTURE OF REINFORCED CONCRETE.

THE probable future of reinforced concrete construction is discussed in the issue of *Beton und Eisen* for January 5th of this year, and although the views expressed in the article have reference to the conditions which are expected to prevail in Germany after the close of the war, they have a certain interest also for British readers. According to this writer, the industry in Germany at present is in a fairly flourishing condition, the stoppage of building which followed immediately on the outbreak of war having been followed by a great demand for construction for military purposes as well as in occupied territories, so that many contracting firms have improved their financial position, and in some cases recovered from losses incurred at the outbreak of the war. In view, however, of the probable severe competition to be faced when peace is declared, the writer urges the necessity of removing all existing prejudices against reinforced concrete construction and the adoption of precautions against the occurrence of any incidents which would tend to destroy public confidence. For this reason it is essential that the fullest enquiry should be made into the causes of the occasional failures which occur, and which are apt to attract an undue amount of attention. Reference is made to certain German bridges which developed defects, and it is stated that investigation has shown defective workmanship to have been largely responsible. This leads up to a discussion of the means of avoiding such occurrences in the future. Competition for contracts is held to have brought about a deterioration of workmanship in some cases, contracts being accepted at such low prices that the temptation is strong to save in material what has been lost in making the estimate. Since the existence of severe competition is inevitable in present circumstances, other measures are necessary in order to save the public from such undesirable consequences.

The only method which appears to the writer of the article to promise success is that of rigid control and inspection of all reinforced concrete work during construction. Unlike steel and similar structural work, concrete is not made in a factory and then transported to the place of use for erection there, but is made *in situ*, often under unfavourable conditions of place and weather. This renders it inevitable that much shall be left to the conscientiousness of the local contractor, especially when the scale of the job is small. Large undertakings are generally placed under the continual supervision of an expert inspector, but this is not possible in the case of small contracts, whilst it is precisely in such work that the need of careful supervision is greatest. Large firms of contractors, such as are usually engaged in the construction of heavy buildings or engineering works, have both the sense of responsibility and the experience which are needed to preserve them from the principal dangers alluded to, and are in the habit of maintaining a constant supervision even when this is not enforced by regulation. The most frequent failures are said to occur in structures which do not require special care or skill, and have the character of repetition work, such as floors. It is said that this branch of reinforced concrete construction has become so little profitable in Germany as to have been abandoned by some of the largest firms and left to small contractors, to whom the temptation to save by sparing material, using leaner mixtures, etc., is greatest.

The writer of the article proposes a considerable extension of the system of official inspection and control. The larger towns already possess a skilled inspectorate, adequately trained in statical methods and in the practical execution of the work. It now remains to build up from this nucleus a staff of expert engineers charged with the general supervision of reinforced concrete construction in town and country. The contractors in each district would become known, and note would be taken of any who had to be warned several times on account of defective execution of work, repeated irregularities leading to exclusion of the firm in question from the right to undertake construction of the kind. Since great responsibilities would be placed on the shoulders of the inspectors, the greatest care would have to be taken that they were selected from men of adequate theoretical training and practical experience.

The conditions which prevail in this country are not entirely similar to those in Germany, but the conclusions reached are nevertheless of some interest to British readers. The German plan of throwing responsibility on to an army of Government officials is not likely to find much favour here, and a reform of the industry from within promises better results. Fortunately, cases of serious failure or scandalous neglect of precautions have been exceedingly rare in Great Britain, but few will deny that there is room for improvement in many directions. The evils of cut-throat competition have been remarked here as elsewhere, whilst it is certain that a knowledge of the special characters of the materials and of the statical principles involved in either building or engineering construction is not as widely diffused as is desirable. Better organisation of the industry is required as well as greater opportunities for the systematic training, both in theory and practice, of the staffs to be charged with the supervision and execution of the work. Above all, research work in reinforced concrete needs to be undertaken in a systematic fashion and machinery devised for making the results of such investigations known to and understood by those persons who are concerned with the material as designers, contractors, or users. The work now in hand under the auspices of the Concrete Institute and the tests undertaken by the British Fire Prevention Committee are both a step in the right direction. It is to be hoped that such investigations will receive encouragement from the authorities interested in research, in conservation, and in reconstruction. But the results of such investigations should not be hidden during their progress. Interim reports should be issued, and any useful information circulated at the earliest moment among those primarily concerned, without, however, such publicity being accorded to important discoveries or to methods of enquiry that might be helpful to the enemy, whose journal we refer to above.

SOME RECENT CONCRETE BLOCK CONSTRUCTIONS.

DURING the past few years the need for the erection of an unprecedented number of buildings in a relatively short time has led to many novel forms of construction and also to the introduction and widespread use of many materials that have hitherto been dismissed as suitable only for the meanest class of building.

To-day the opinion is widely expressed that the use of many of these materials has been a mistake, and, to take one example only, it is certain that if concrete had been more generally used in place of timber a great initial saving would have been made, not to mention the maintenance charges. Another point to bear in mind is the fire-resistance of concrete in comparison with timber. These considerations are highly important, especially if the need for the buildings should continue for several years longer.

On the completion of hostilities another period of intensive building will at once begin, for thousands of houses must be rapidly erected for the men back from the Front, and alterations to industrial buildings and works that have been held up for a time will also absorb vast quantities of building material.

Beyond this, however, the inevitable congestion of traffic and the difficulties of transport will play their part; and if, therefore, some method of construction can be used in which the transportation of the raw material is small in comparison to the labour required, the peril of a famine of constructive materials will have been greatly averted.

It must also be remembered that when demobilisation occurs much surplus man power will be available, and such semi-skilled labour can be profitably and wisely employed in concrete constructions until the needs of our complex civilisation are somewhat adjusted.

There is, however, no reason why the construction of houses, farm buildings and factory and engineering structures should inevitably be of brick construction, for in many districts where sand and gravel suitable for the aggregate are to hand or close to the site, construction in concrete will prove to be the cheapest method of building.

We have therefore great pleasure in illustrating the following buildings which have lately been constructed of concrete blocks, and which have given great satisfaction to all connected with their erection and uses.

Figs. 1 to 5 show some of the buildings forming part of a large military establishment, and, whilst of light construction that can be rapidly erected, they

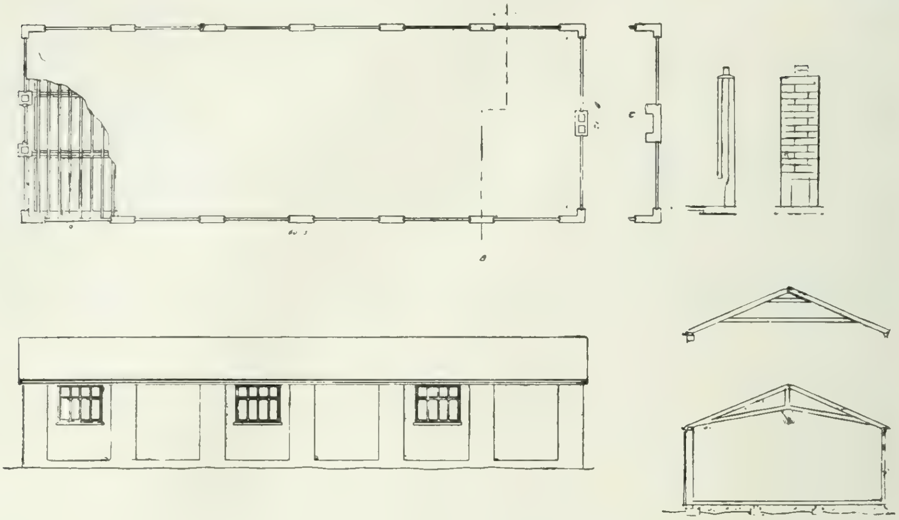

FIG. 1. PLANS, SECTIONS, ELEVATIONS.

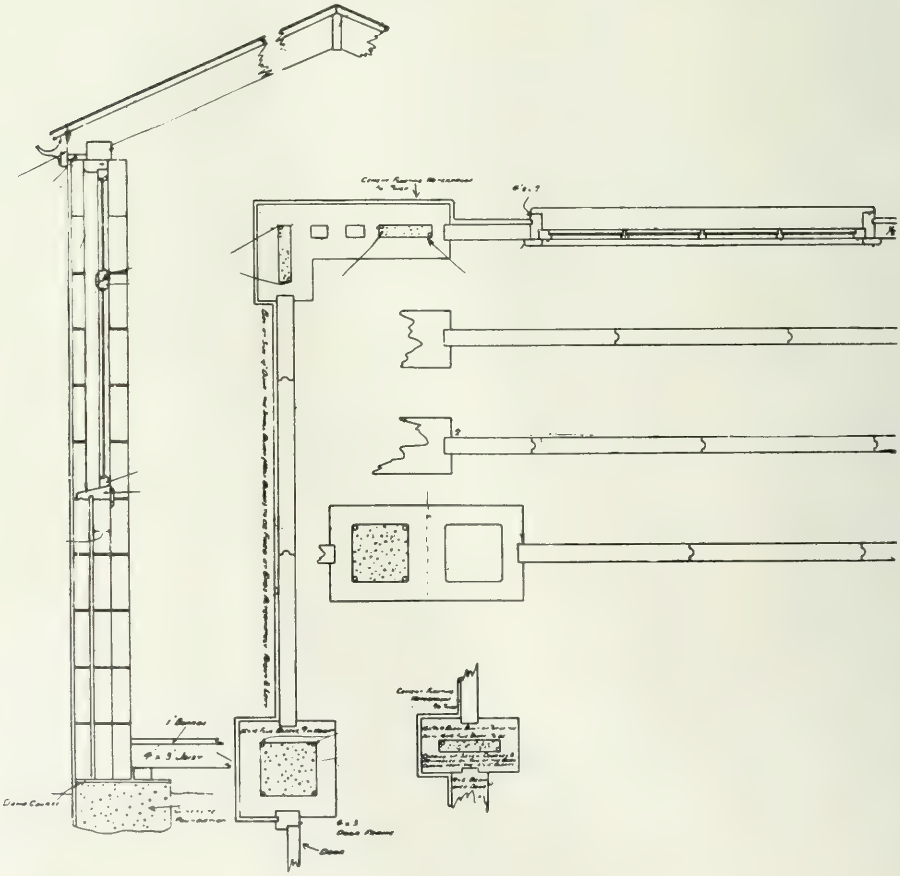

FIG. 2. DETAILS OF CONSTRUCTION.

possess the elements of durability and good appearance. *Fig.* 4 shows the interior of a hospital hut. As will be seen, the walls were not plastered, but merely colour-washed, which gives a pleasing and sanitary finish to the building.

As will be seen from *Figs.* 1 and 2, the whole construction is standardised, and to give greater stability the corner blocks and the piers spaced at regular intervals along side and end walls are moulded hollow and threaded over ordinary reinforcing rods, where such reinforcement is necessary.

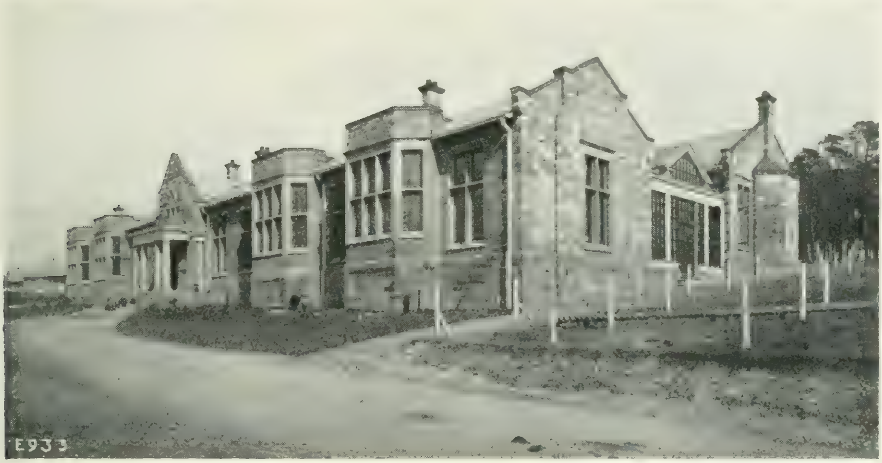

Fig. 3. Recent Concrete Block Buildings.

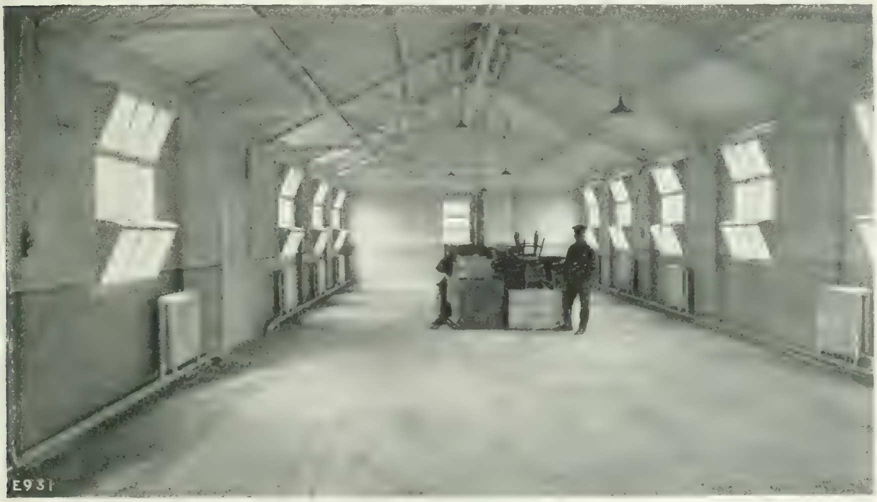

Fig. 4. Interior of a Hospital Hut.

Concrete is then filled in, and thus the whole framing of the building is of reinforced concrete carried out without the necessity of timber shuttering or false work and the use of skilled carpenters.

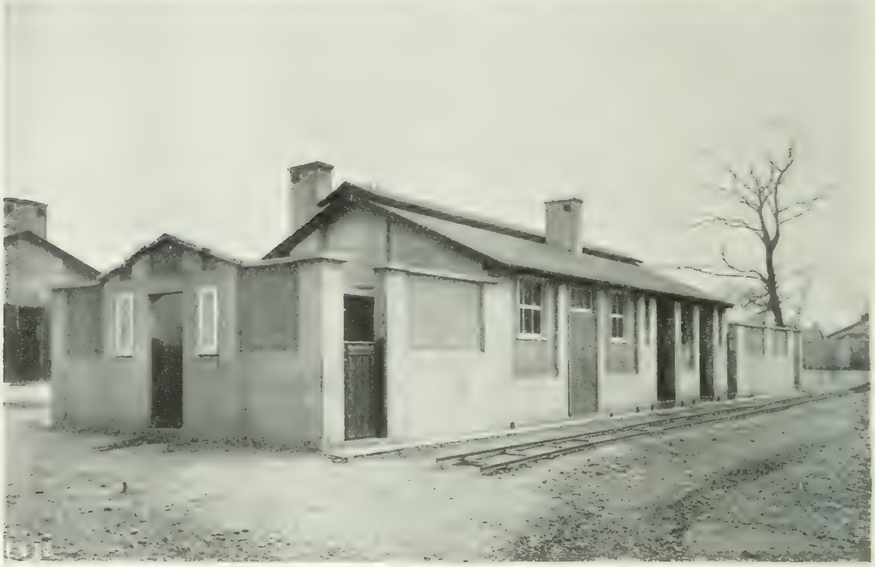

Fig. 5. A Recent Concrete Block Building.

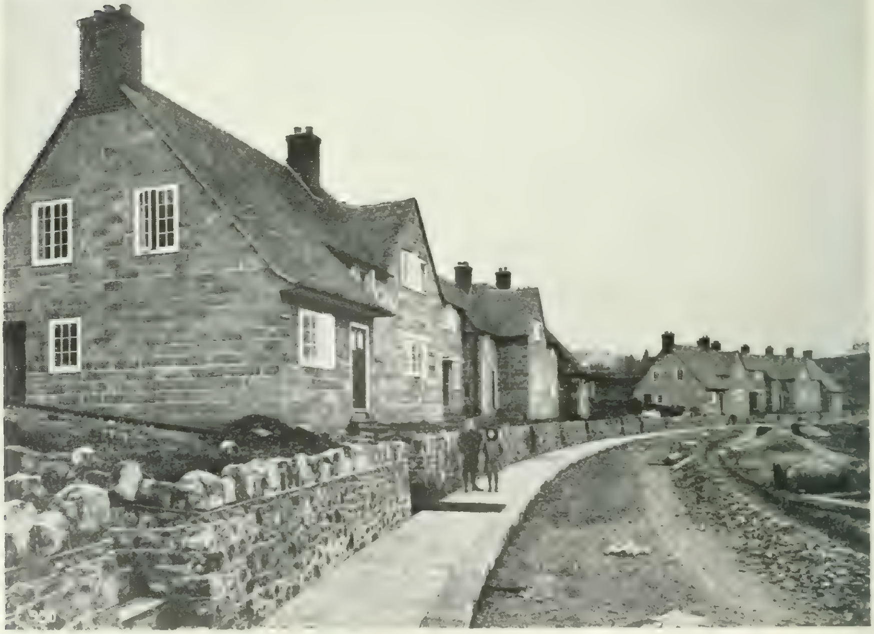

Fig. 6. Some Cottages at Chepstow.

Special blocks are formed for the fireplaces and chimneys, and the patentees claim that single-story buildings, 60 ft. by 20 ft., have been erected in lots of fifty and upwards at the rate of one per day.

The wall fillings between piers are also of standard size slabs, and it will be readily realised that "Unit" construction of this type lends itself to economical and rapid constructions.

Fig. 6 shows part of a housing scheme which is being carried out at Chepstow (Mon.) for a shipbuilding and engineering firm from the designs of Messrs. Dunn, Watson and Curtis Green, of 35, Lincoln's Inn Fields.

The clients have shown the most commendable spirit in this scheme, as they have spared no effort to make the cottages models of good building, with ample accommodation and artistic appearance.

The site is a very picturesque one, in a valley outside the ancient walls of the town, and as the contours of the ground are very irregular, the design of each block has been varied to suit its particular position; while the prospect and aspect have been carefully studied in each case.

The difficulty of getting bricks, and the presence of good material on the site as an aggregate for concrete led to the adoption of the "Winget" concrete block system for all walls and partitions. The general texture and colour of these external walls is very pleasing, and the effect, when seen, would remove the prejudice that exists among many designers against the appearance of concrete as an exposed surface. External walls are constructed as cavity walls with two thicknesses of 4-in. blocks, having a 3-in. space between, and iron ties as usual.

The accommodation varies in each house, but in those illustrated there are in each of the five houses in the block a parlour, three bedrooms, kitchen, scullery, bathroom, fuel store, larder, and front and back porches. The backs of the houses have been studied as much as the front, and the effect is equally pleasing. The roofing is of sand-faced tiles with swept valleys and plain roll ridges.

PROBLEMS IN THE THEORY OF CONSTRUCTION.

THE STRENGTH OF PILLARS.

By EWART S. ANDREWS, B.Sc., Eng.; M.C.I.

Introductory: Euler's Formula.—The problem of the strength of pillars has been attacked by hundreds of investigators since Euler first derived the formulæ which bear his name, and which have been very widely misunderstood. Euler's formula is the result of a mathematical analysis, which assumes that a pillar, initially straight and centrally loaded, becomes bent due to some accidental cause, and then proceeds to calculate the load necessary to produce a deflected form due to bending moments only which agrees with the deflected form assumed. The solution of the resulting differential equation gives the strange result that this critical load is independent of the accidental deflection assumed; this means that if the load carried by the pillar is less than the critical load, the pillar will resume its straight form when the accidental deflecting cause is removed, but that if the load is not less than this critical value, the pillar will continue to deflect. This deflection will not continue quite indefinitely, as is usually stated, because the assumptions made in deriving the formula no longer hold after the radius of curvature becomes comparable with the length of the pillar; this point is dealt with at length by Mr. W. Alexander, M.Inst.C.E., in his book* on "Columns and Struts."

Euler's formula for a pillar hinged at the ends is usually expressed as:—

$$W = \frac{\pi^2 EI}{l^2} \qquad (1)$$

where W = critical load on pillar
E = Young's modulus
I = least moment of inertia of pillar section
l = length of pillar
$\pi = 3 \cdot 14159$

We may rewrite this, after putting $I = Ag^2$, as

$$c_E = \frac{\pi^2 E}{\left(\frac{l}{g}\right)^2}$$

where c_E = critical pressure per unit area of pillar
g = least radius of gyration of pillar section

For mild steel we may write $E = 30 \times 10^6$ lbs. per sq. in. $= 30 \times 10^3$ kips per sq. in. (1 kip = 1000 lbs.).

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* E. and F. N. Spon, Ltd., London.

And thus obtain

$$c_E = \frac{296090^*}{\left(\frac{l}{g}\right)^2} \text{ kips per sq. in.} \qquad (2)$$

Corrected Formulæ for Straight Pillars Centrally Loaded.—It will be noted that this formula takes no account of the direct compression on the pillar, with the natural result that the compressive strength of the material does not appear in the formula. To correct for this deficiency a very large number of formulæ have been devised which have for their object to make the critical load agree with the compressive strength of the material for dumpy pillars and to approach Euler's results for slender pillars. Among these formulæ the best known are Rankine's formula and Johnson's formula. The straight-line formulæ (often called American formulæ) are also usually classified with these, although their attempt to follow the Euler figures is much less exact. All of these formulæ are intended for pillars which are initially quite straight and are centrally loaded, conditions which never obtain in practice.

The straight-line formulæ have been adopted freely in official regulations, largely, we believe, on account of their simplicity; we contend that this simplicity is usually obtained at the expense of economy, and that it is more imaginary than real in practical design.

We will deal with this point again later, but it may now be pointed out that few practical designers have sufficient time to use a formula at all; they use a table or a diagram derived from the formula, and once that table or diagram is made, it makes not the slightest difference in its use whether the formula is a simple one or not. In the regulations governing the erection of steel-frame buildings under the London County Council, the straight-line formula is employed, but it is given in the form of a table, and it would have been just as easy to have made that table more accurate.

Formula for Centrally-Loaded Pillars not Initially Straight.—No pillar in practice is mathematically straight, and it therefore becomes desirable to derive formulæ assuming slight initial deflection due to crookedness of the pillar. Two formulæ based upon such considerations are well known in practice as Fidler's† formula and Moncrieff's‡ formula. These formulæ approximate much more closely to true theory and with tests than the others which we have mentioned, but owing to their complicated form and length of derivation they are practically never dealt with in text-books; when they are referred to at all they are generally dismissed with the implied suggestion that they are of less importance than the Rankine formula. The following formulæ are obtained by much shorter reasoning than the Fidler or the Moncrieff formula and are, we believe, quite as reliable.

Case 1. Pin-Jointed or Hinged Ends.—We will take as our standard case that in which the ends are hinged; we do this because the analysis is simpler, and because it is easy to give equivalent lengths in terms of hinged ends for other methods of end fixing.

Assuming that the pillar is initially bent, we will calculate the further deflection caused by the bending moment; we can then calculate the bending stress at the centre and add to it the stress due to the direct load. This gives us the maximum stress in the pillar for the given load, and by equating this to the yield point of the material we shall obtain an expression which enables us to calculate the ultimate stress in the pillar. This theory differs from Eule'rs in that there is a definite deflection for each load. It also makes the ultimate stress depend upon the compressive strength of the material, and not only upon its elastic modulus.

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* See Table I.

† "A Treatise on Bridge Construction." Griffin & Co., London.

‡ Proc. Am.Soc.C.E., Vol. XLV.

We will assume that the pillar is initially slightly bent as shown in the fine line in *Fig.* 1, and that after the load is applied the deflection increases to the form shown by the heavy line; we will assume that the initial central deflection or eccentricity is e_o, and that the initial curve is of sine form; the sine form is adopted to assist the mathematics, and it has been shown that the assumption of circular or parabola form gives almost identical results.

Consider a point P at which the initial eccentricity is given by

$$x_o = e_o \cos\left(\frac{\pi y}{l}\right) \qquad (3)$$

and let the deflection from this initial position caused by the load W be x; then the bending moment at the point P is given by

$$\begin{aligned} B &= W\,(x + x_o) \\ &= W\left\{x + e_o \cos\left(\frac{\pi y}{l}\right)\right\} \qquad (4) \end{aligned}$$

Since the deflection is small we may, as usual, write

$$B = -EI\,\frac{d^2x}{dy^2}$$

$$i.e., \quad \frac{d^2x}{dy^2} = -\frac{W}{EI}\left\{x + e_o \cos\left(\frac{\pi y}{l}\right)\right\}$$

or writing, for simplicity, $\dfrac{W}{EI} = m^2 \qquad (5)$

$$\frac{d^2x}{dy^2} = -m^2\left\{x + e_o \cos\left(\frac{\pi y}{l}\right)\right\} \qquad (6)$$

The general solution of this differential equation is

$$x = A \sin my + C \cos my + \frac{e_o m^2 l^2}{(\pi^2 - m^2 l^2)} \cos\frac{\pi y}{l} \qquad (7)$$

To obtain the particular solution for our problem we note that $x = o$, for $y = +\dfrac{l}{2}$ and $-\dfrac{l}{2}$

For this to be possible we must have

$$A = o$$

then taking $x = +\dfrac{l}{2}$ we have

$$\begin{aligned} o &= C \cos\frac{ml}{2} + \frac{e_o m^2 l^2}{(\pi^2 - m^2 l^2)} \cos\frac{\pi}{2} \\ &= C \cos\frac{ml}{2} + o \end{aligned}$$

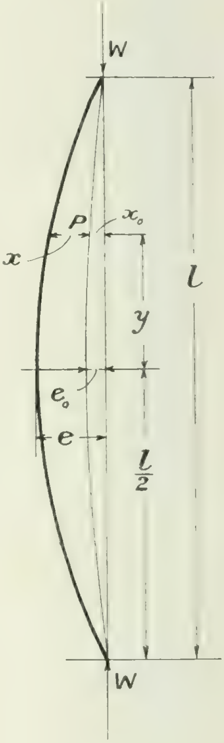

FIG. 1.

$\cos\frac{ml^2}{2}$ can only be $=o$ if $ml=\pi$: *i.e.*, $m^2l^2=\pi^2$;

$$i.e.,\ \frac{W}{EI}\,.\,l^2=\pi^2 \text{ or } W=\frac{\pi^2EI}{l^2}$$

This is the value of W by Euler's formula, and in all the cases which we shall consider W will be less than that, so that $\cos\frac{ml}{2}$ is not $=o$. $\therefore C=o$.

Our equation (5) therefore reduces to

$$x=\frac{e_0m^2l^2}{(\pi^2-m^2l^2)}\cos\frac{\pi y}{l} \tag{8}$$

The maximum value of x occurs when $y=o$, and is given by

$$x_{max}=\frac{em^2l^2}{(\pi^2-m^2l^2)} \tag{9}$$

$\therefore$ Total deflection or effective eccentricity at the centre of the pillar is given by

$$\begin{aligned} e&=e+x_{max}\\ &=e_0\left(1+\frac{m^2l^2}{\pi^2-m^2l^2}\right)\\ &=e\left(\frac{m^2l^2}{\pi^2-m^2l^2}\right)\\ &=\frac{e}{\left(1-\frac{m^2l^2}{\pi^2}\right)} \end{aligned} \tag{10}$$

Now let c_E be the Euler critical stress, and let c_p be the actual intensity of load on the pillar $=\frac{W}{A}$, we then have

$$\begin{aligned} \frac{m^2l^2}{\pi^2}&=\frac{W\,.\,l^2}{EI\pi^2}=\frac{W}{A}\div\frac{\pi^2E}{\left(\frac{l}{g}\right)^2}\\ &=\frac{c_p}{c_E} \end{aligned}$$

$\therefore$ equation (8) becomes

$$d_n=\frac{e}{\left(1-\frac{c_p}{c_E}\right)} \tag{11}$$

The resultant compressive stress at the centre of the pillar if n is the distance from the compression edge to the neutral axis is equal to

$$\begin{aligned} \text{Resultant stress}&=\frac{W}{A}+\frac{Bn}{I}=\frac{W}{A}\left(1+\frac{en}{g^2}\right)\\ &=c_p\left(1+\frac{en}{g^2}\right) \end{aligned} \tag{12}$$

Failure of the pillar in a ductile material will occur when this resultant stress becomes equal to the *yield-point stress* c_y in the material; we then have

$$\begin{aligned} c_y&=c_p\left(1+\frac{en}{g^2}\right)\\ &=c_p\left\{1+\frac{e_0n}{g^2\left(1-\frac{c_p}{c_E}\right)}\right\} \end{aligned} \tag{13}$$

If we write $\frac{e_o n}{g^2} = \alpha$, this becomes

$$c_y = c_p\left\{1 + \frac{\alpha c_E}{c_E - c_p}\right\}$$

$$i.e., \; c_y - c_p = \frac{\alpha c_p c_E}{c_E - c_p}$$

$$i.e., \; c_p^2 - c_p\{c_y + (1+\alpha)c_E\} + c_E c_y = o$$

$$\text{or,} \; c_p = \frac{\{c_y + (1+\alpha)c_E\} - \sqrt{\{c_y + (1+\alpha)c_E\}^2 - 4c_y c_E}}{2} \qquad (14)$$

For any given material c_y and c_E are known, and values of the resulting critical pillar stress can then be found for any given pillar.

If the material is a brittle one, we may substitute the ultimate compressive stress c_u for c_y, remembering that if the material is weaker in tension than compression we ought to consider the resultant tensile stress which will be equal to $c_p\left\{\frac{e_o n}{g^2\left(1 - \frac{c_p}{c_E}\right)} - 1\right\}$ and equate that to the ultimate tensile strength.

Mr. W. Alexander, in his book which we have previously referred to, has investigated the strength of pillars with great attention to detail in the mathematical treatment; he investigates the length of the arc of the deflected pillar, but does not give his results in a form suitable for practical design without the very laborious calculation necessary to prepare suitable diagrams; we believe that the results of our treatment are as accurate as practical conditions make possible and that it is unnecessary to go into such great refinement in the theoretical treatment as Mr. Alexander advocates.

It is interesting to consider the result in the above formula when the original eccentricity $e_o = o \; \therefore \; \alpha = o$; we then have

$$c_p = \frac{c_y + c_E - (c_y - c_E)}{2} = c_E;$$

the other root of the quadratic equation would have given $c = c_{py}$, and this agrees with the correct interpretation of Euler's formula.

Application to Steel Pillars.—For steel we have $E = 30 \times 10^6$ lbs. per sq. in., so that the values of c_E given in equation (2) may be employed; as these Euler stresses occur frequently in the formulæ, we give the following tabulated values—

TABLE 1. VALUES OF EULER STRESSES C_E FOR STEEL.

$\frac{l}{g}$	20	40	50	60	70	80	90	100	110	120	130	140	150	160	180	200
Euler stress c_E (kips per sq. in)	740·2	185·0	118·4	82·23	60·43	46·26	36·55	29·61	24·47	20·56	17·52	15·11	13·16	11·56	9·137	7·402

For mild steel we may take the yield point at 45,000 lbs. per sq. in. = 45 kips per sq. in.

Our equation (14) for the ultimate pillar stress then becomes

$$c_p = \frac{\{45 + (1+\alpha)c_E\} - \sqrt{\{45 + (1+\alpha)c_E\}^2 - 180\,c_E}}{2} \qquad (15)$$

The most convenient method of dealing with a formula of this kind, for use under varying conditions of factor of safety is to call

$$\frac{c_y}{c_p} = \text{Pillar stress coefficient} = Q.$$

We can then prepare a diagram as shown in *Fig.* 2, which gives values of Q

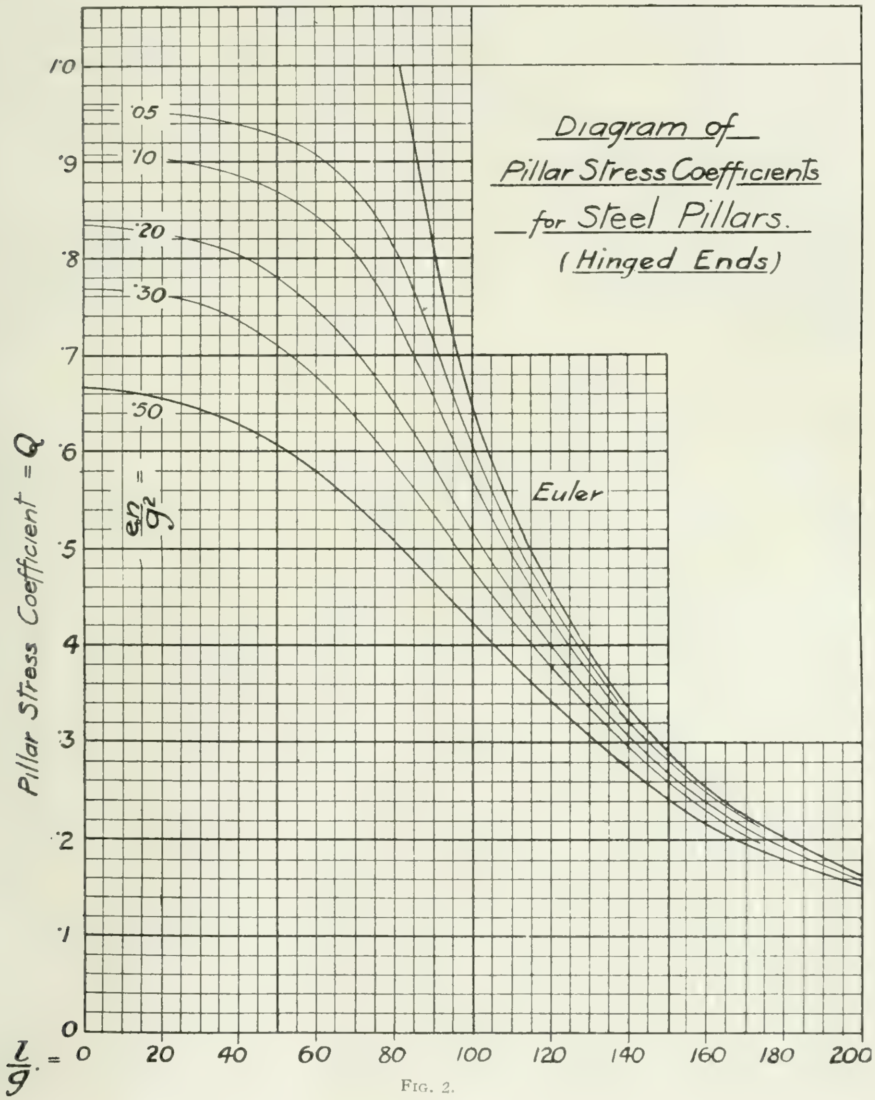

FIG. 2.

for various values of $\frac{l}{g}$ for different values of $\frac{e_a n}{g^2}$; for most practical sections $\frac{e_a n}{g^2}$ will vary between ·05 and ·2, and should be taken higher for slender sections such as angles than for stiff sections.

Prof. Basquin* states that in the kind of pillar occurring in steel frame buildings a crookedness of $\frac{1}{16}$ in. for every 5 ft. in length should be allowed for.

Numerical Example.—Take a pillar with hinged ends 14 ft. long, built up of a 12 in. × 6 in. × 44 I beam with $8 \times \frac{5}{8}$ plates on each side.

For the section we have $g = 1{\cdot}81$ in.

$$n = 4 \text{ in.}$$

$$\frac{l}{g} = \frac{14 \times 12}{1{\cdot}81} = 93$$

$$A = 22{\cdot}9 \text{ sq. in.}$$

e_o we may take $= {\cdot}18$ in.

$$\therefore \alpha = \frac{e_o n}{g^2} = \frac{{\cdot}18 \times 4}{1{\cdot}81^2} = {\cdot}22$$

Reading from our diagram by running up vertically from the point 93 on the base to a point beyond the ·3 curve equal to $\frac{4}{5}$ of the distance between the ·3 and the ·2 curve, we find $Q = {\cdot}55$.

For mild steel we may take a factor of safety of three for ordinary equivalent dead-loading conditions, *i.e.*, a safe short-pillar stress of 15 kips per sq. in.

$$\therefore \text{ Safe stress for one pillar} = {\cdot}55 \times 15$$
$$= 8{\cdot}25 \text{ kips per sq. in.}$$

$$\therefore \text{ Safe load} = 8{\cdot}25 \times 22{\cdot}9 = 189 \text{ kips.}$$

The load allowed under the L.C.C. Steel Frame Act on this pillar is 112 kips.

It might be suggested that this example, which we have purposely selected so as not to present the L.C.C. figures at unreasonable disadvantage, is hardly a fair comparison since the ends are seldom hinged in practice, and it is well known that low stresses are allowed for hinged ends under that Act to encourage designers to use rigid connections.

We will therefore anticipate some of our later treatment in order to take the pillar as fixed at one end and hinged at the other; this is the method of fixing usually taken by the district surveyors for a pillar fixed in the manner usual in steel frame construction.

In this case we take the length as equivalent to $\frac{l}{1{\cdot}4}$, so that for $\frac{l}{g}$ we take $\frac{93}{1{\cdot}4}$ = 66 approx.

From our diagram we read $Q = {\cdot}71$

$$\therefore \text{ Safe load} = \frac{189 \times {\cdot}71}{{\cdot}55} = 244 \text{ kips.}$$

The load allowed under the L.C.C. Act = 164 kips. If, as we believe has been proved experimentally, the values given by our diagram are absolutely safe, there is a great waste of steel in the pillars designed in accordance with the L.C.C. Act.

For most cases in practical design of pillars centrally loaded and as straight as possible, we do need to go into such refinement as we have done to calculate $\frac{e_o n}{g^2}$ for each section; in such cases we can choose a value of this quantity varying with $\frac{l}{g}$, which will give us one diagram for use in practice.

(*To be continued.*)

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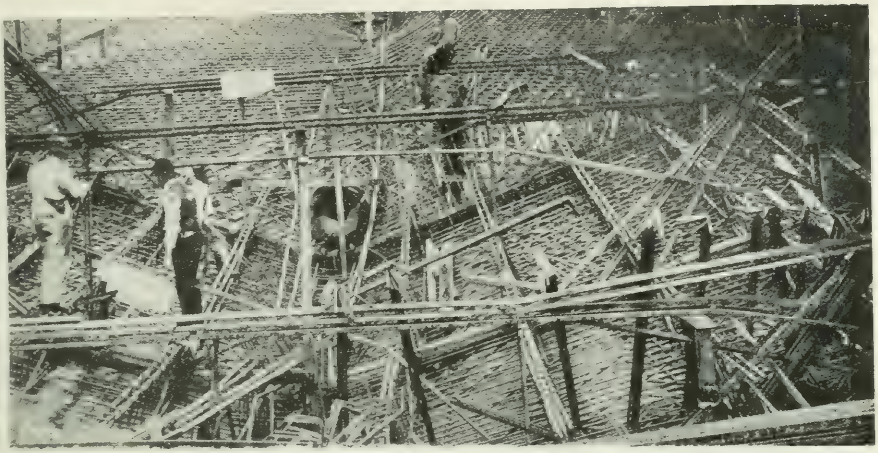
* Western Society of Engineers, 1914.



Stern, showing Propeller Shaft Sleeve.

CONCRETE SHIPBUILDING.

A LARGE REINFORCED CONCRETE SHIP IN AMERICA.

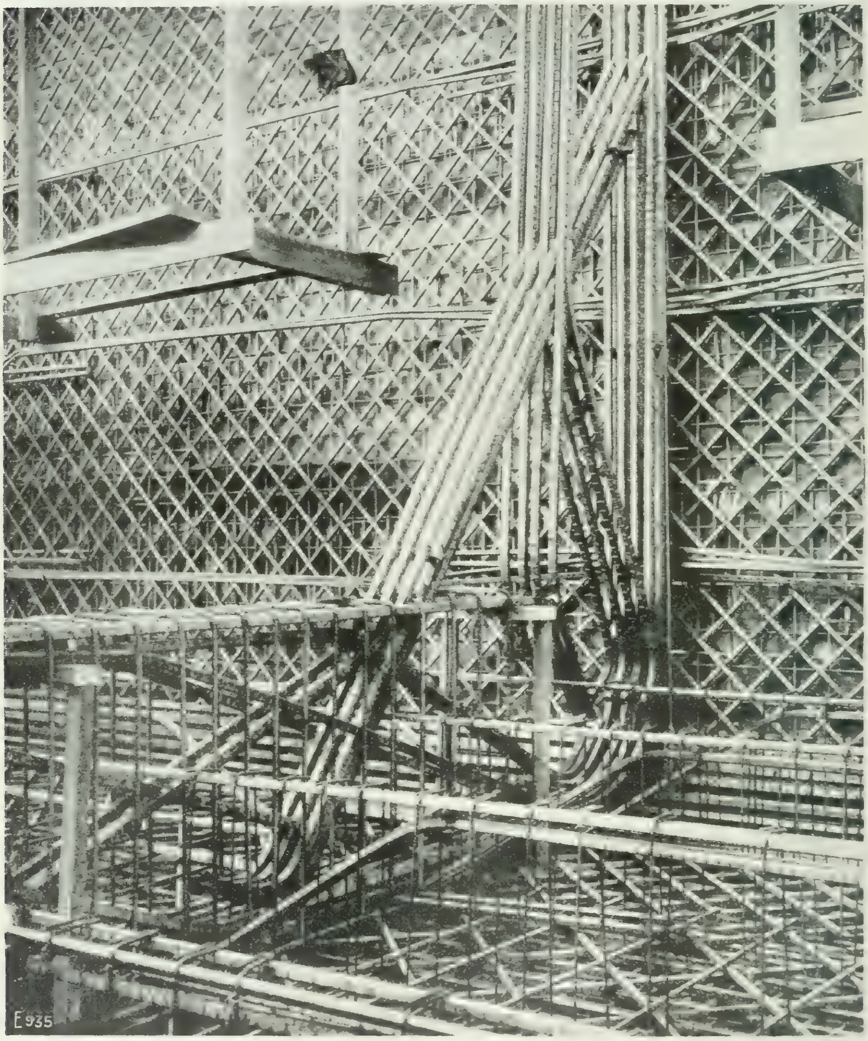
In recent issues we have been able to present illustrations and particulars regarding concrete ships and concrete barges in various parts of the world, but the following illustrations, taken from *Engineering Men's Record*, of a large ship which, at the time of going to press, is nearing completion at San Francisco, are of special interest, inasmuch as they deal with a vessel built on a much larger scale than any heretofore referred to.

The construction of the ways for the building of the ship, here described, was commenced in August last in San Francisco, and the laying down of the ship was started in September. The vessel is designed for a displacement of 7,900 tons and a deadweight carrying capacity of 5,000 tons. It is stated that had it not been for some change in the plans and the employment of a new naval architect the ship would have been ready for launching in February of this year.

The vessel is 336 feet long over all, 45 feet in beam and 31 feet deep to the upper deck. The draft loaded will be 24 feet. The ship will be equipped with Scotch marine boilers and 1,750 h.p. triple expansion engines, and the speed will be 10 knots.

For obvious reasons it is not possible to give details of the design at this stage, but the accompanying illustrations give a very clear idea of the general plan and design.

It is interesting to note that this boat is not steel frame, but is constructed with a patented system of steel reinforcing bars and wire netting.



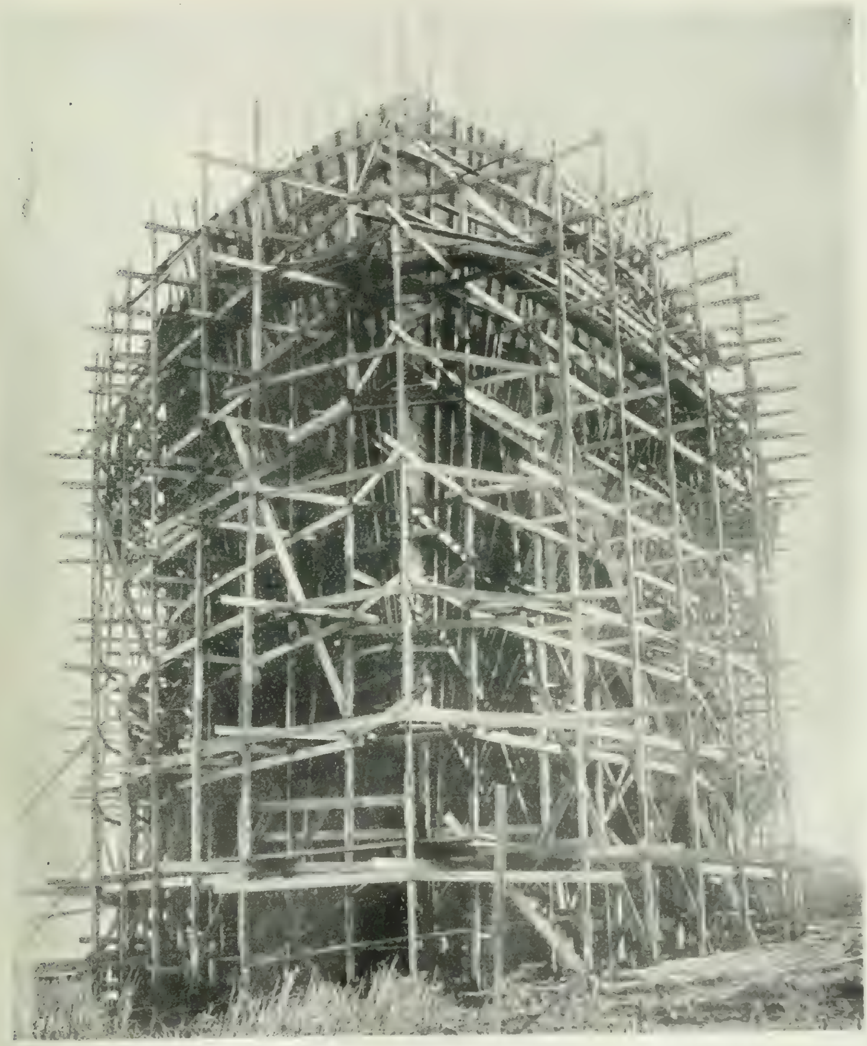
View showing some of the steel work.

A Large Reinforced Concrete Ship in America.

The thickness of the skin varies in order to make provision for the additional strains at various points. The bulkheads will be of concrete.

Four other large vessels of this same general type are to be built at

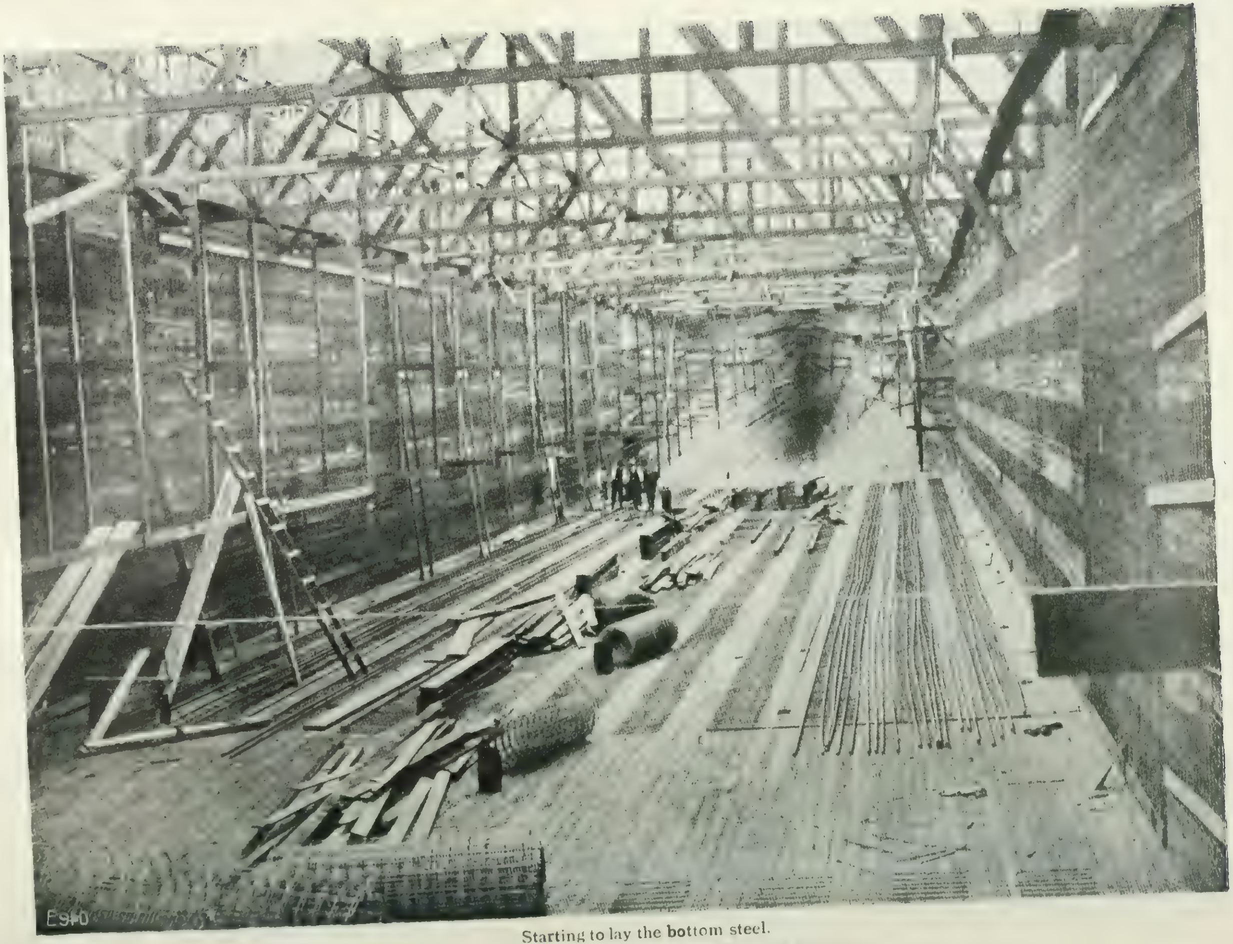
San Francisco as soon as the present ship, now nearing completion, is launched.



View showing Prow of Ship.

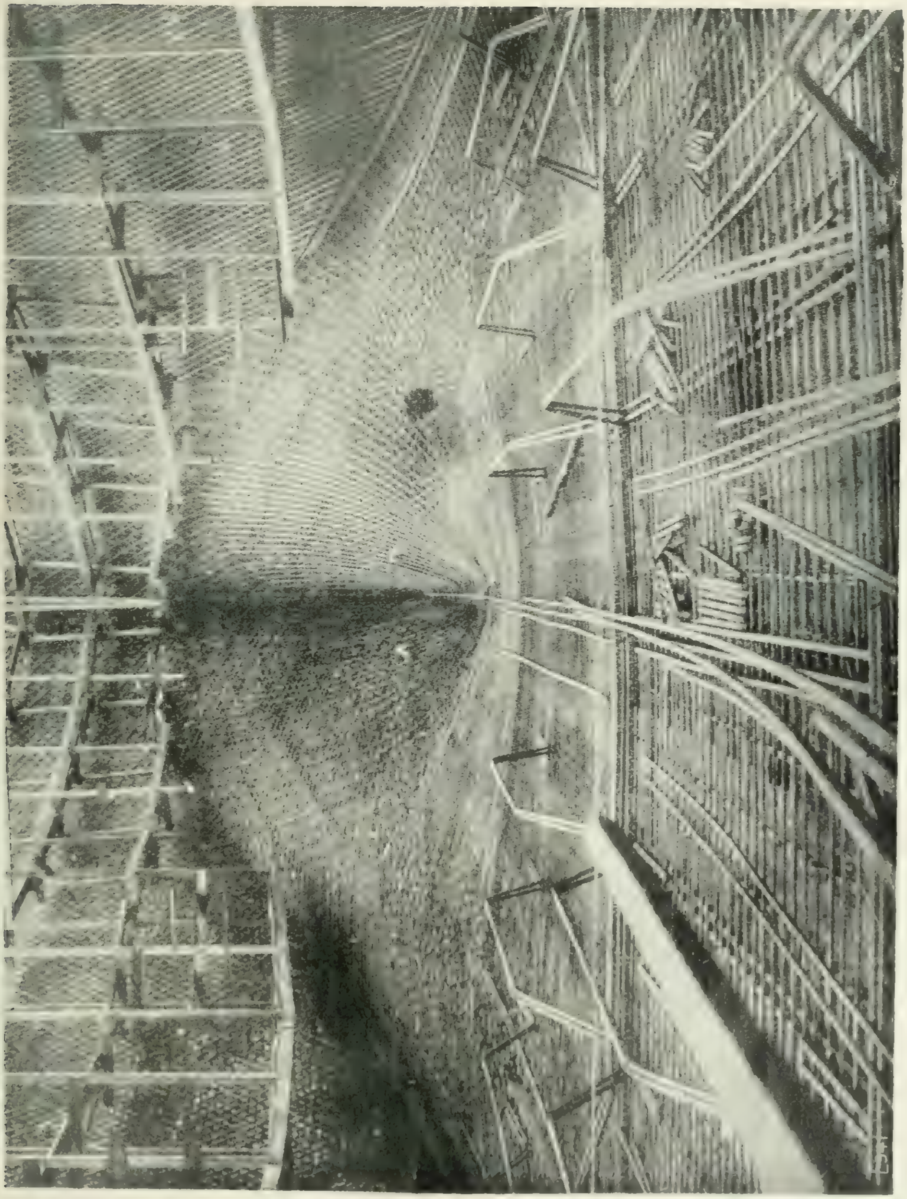
A Large Reinforced Concrete Ship in America.

Special interest is being taken in the construction of this boat by the Bureau of Standards at Washington, as well as by some of the shipping authorities in this country.



Starting to lay the bottom steel.

A LARGE REINFORCED CONCRETE SHIP IN AMERICA.

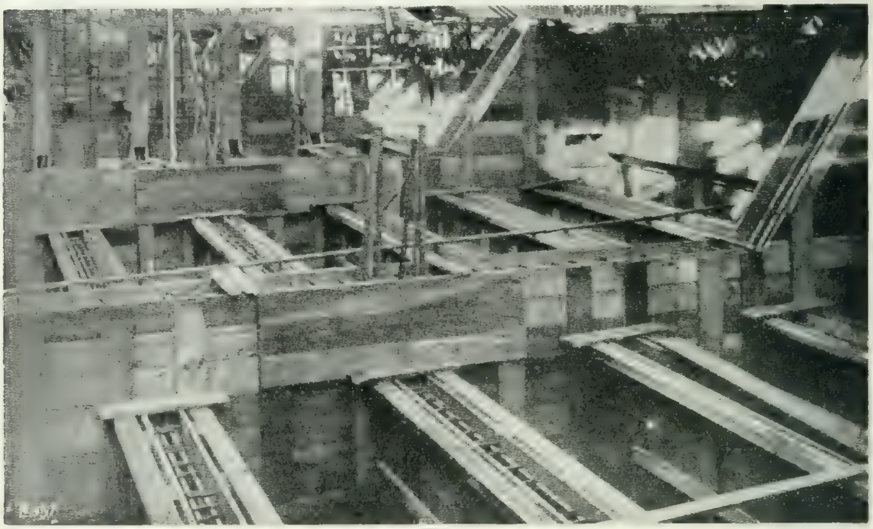


Shell Reinforcement of Prow in place.

A Large Reinforced Concrete Ship in America.

The vessel is being built by the San Francisco Shipbuilding Co. under the superintendence of Messrs. McDonald & Kahn, consulting engineers and contractors. The naval architect is Mr. E. L. Stuart.

We hope at a later date to be able to give a photograph of the completed ship, together with some further details.



Wooden Forms in place

A Large Reinforced Concrete Ship in America.

Some Notes on Shipbuilding.—At the annual meeting of the British Corporation for the Survey and Registry of Shipping, held in Glasgow last month, Mr. Fred J. Stephen, Chairman of the Technical Committee, made the following interesting remarks in reference to concrete shipbuilding:—"Reinforced concrete construction was being applied to shipbuilding to such an extent that it had advanced more in months than it would have done in years of normal life. Many designs had been considered by the Committee after careful analysis in the light of all available experience. Some had been rejected and others chosen for acceptance as sound experimental propositions, and it should not be many months before some were subjected to the test of practical experience—of course, in ships of relatively small tonnage. It remained to be proved from actual experience if the advantages outweighed the disadvantages, and, when the material has been proved suitable for the work to be done, whether cheapness and rapidity of construction and saving in upkeep would make these ships strong competitors of the lighter and more costly steel ship. If the serious development of the 'cast' ship should lead to the discovery of a composition more elastic than concrete, in the sense of stretching and closing without cracking, to a degree which would harmonise with the movements of steel under stress, then there could be no doubt as to the great possibilities of this form of shipbuilding, because the economy in it was practically that which casting had over forging."

THE SETTING OF CEMENTS AND PLASTERS.

In continuation of the Papers published last month, we now give abstracts of the remaining Papers read at the meeting of the Faraday Society.—ED.

THE paper by Mr. A. A. KLEIN, of Worcester, Mass., dealt with the "Constitution of Portland Cement and the Hydration of its Various Constituents." After defining Portland cement in the customary manner, the author outlined the micro-petrological methods used for investigating its constitution, and pointed out the ease with which tricalcium silicate and tricalcium aluminate may be confused when a thin section of cement is examined.

He explained that there are, in general, three types of theories concerning the active principle of cement: (1) That it is a solid mutual solution of various calcium silicates and calcium aluminates to which each investigator ascribed formulæ; (2) that it is a definite lime, silica, alumina compound; and (3) that Portland cement is composed of separate silicates and aluminates some or all of which are hydraulic.

There was a time, even very recently, when the solid solution theory was most universally held. Tornebohm, Michaelis, Shott, and Glasenapp, among others, came to this conclusion. In the United States, Clifford Richardson concluded that the clinker consisted essentially of a solid solution of tricalcium aluminate in tricalcium silicate, but later admitted this conclusion to be erroneous.

Of the investigations which appeared to prove the existence of a ternary compound occurring universally in cement, that of Ernest Jänecke * was the most comprehensive and scientific. The petrographic description of his supposed compound $8CaO.Al_2O_3.2SiO_2$, was very meagre, and investigations at the Bureau of Standards and at the Geophysical Laboratory have failed to produce it, and have shown that a melt of its composition generally crystallises as $3CaO.SiO_2$, $2CaO.SiO_2$, and $3CaO.Al_2O_3$.

Finally, of the investigations which led to the conclusion that cement is composed of separate silicates and aluminates, those of the Geophysical Laboratory on the binary systems $CaO–SiO_2$, $CaO–Al_2O_3$, $Al_2O_3–SiO_2$ and on the ternary system $CaO–SiO_2–Al_2O_3$ have been the most serviceable. They suggested † that the constituents of "Portland cement clinker within the concentration limits set by Richardson when in equilibrium may exist in the following combinations depending primarily upon relatively small changes in the quantity of lime present:

I.	II.	III.	IV.	V.
CaO	$3CaO.SiO_2$	$2CaO.SiO_2$	$2CaO.SiO_2$	$2CaO.SiO_2$
$3CaO.SiO_2$	$2CaO.SiO_2$	$3CaO.Al_2O_3$	$5CaO.3Al_2O_3$	$2CaO.Al_2O_3.SiO_2$
$3CaO.Al_2O_3$	$3CaO.Al_2O_3$	$5CaO.3Al_2O_3$	$CaO.Al_2O_3$	$CaO.Al_2O_3$

"Richardson's typical cement corresponds to Class II." Furthermore, "if solid solutions are formed, they are very limited in extent, and are not sufficient to affect the optical properties of either silicate, the lime, or the aluminate." Later, the Bureau of Standards ‡ made and studied mixtures which gave cement clinkers of various chemical compositions, and practically all the predictions of the Geophysical Laboratory were verified. Portland cement within the composition limits considered to be good practice was found to be a mixture of Beta $2CaO.SiO_2$, $3CaO.SiO_2$, and $3CaO.Al_2O_3$. Of these three, Beta $2CaO.SiO_2$ occurs in the greatest proportions, CaO does not occur except in underburned clinker, and the presence of $5CaO.3Al_2O_3$ may result from underburning or from a mixture low in lime and high in alumina. Class I, as given above, must be burned at higher temperatures than can be produced economically. Moreover, free lime is undesirable in the finished product. Class II is typical of good cement. The constituents of Class III were found in abnormally low-limed cements, in which " dusting of the clinker " is a serious and frequent occurrence, and the setting generally erratic. Classes IV and V were never found in commercial Portland cements.

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* *Zeits. Anorg. Chem.*, lxxiii, 200–22; lxxiv, 428.

† *Jour. Ind. Eng. Chem.*, iii, 1–13.

‡ "Concrete-Cement Age," *C.M.S.*, January, 1913, pp. 3–7.

According to Rankine[*] when a mixture of pure oxides—corresponding to Class II, and with a composition of CaO 68·4 per cent., Al_2O_3 8·0 per cent., and SiO_2 23·6 per cent.—is slowly heated, the first change is the evolution of the CO_2; the lime then unites with the other components to form the compounds $5CaO.3Al_2O_3$ and $2CaO.SiO_2$ probably in the order named, since the former has a lower melting-point than the latter: subsequently these two compounds unite in part with more lime, and the compounds $3CaO.Al_2O_3$ and $3CaO.SiO_2$ appear. This formation of the last two compounds is materially facilitated when a portion of the charge having already melted, it acts as a flux or solvent. The temperature at which this flux first appears is 1,335° C., the eutectic temperature for the three compounds $2CaO.SiO_2$, $5CaO.3Al_2O_3$, and $3CaO.Al_2O_3$. At a temperature somewhat above 1,335° C. the compounds $5CaO.3Al_2O_3$ will have completely melted in the flux, and the formation of $3CaO.Al_2O_3$ is soon completed. The substances present as crystals at this stage are $3CaO.SiO_2.Al_2O_3$, $2CaO.SiO_2$, and free CaO. As the temperature is raised still further the amount of flux increases and the rate of combination of $2CaO.SiO_2$ to form $3CaO.SiO_2$ increases. For finely-ground raw materials of the above composition a temperature of about 1,650° C. is required for complete burning.

The foregoing is accurate in the case of pure oxides, but investigation by the Bureau of Standards has shown that the burning temperature of the commercial product varies within wide limits. Thus it is possible to obtain a mixture which, when burned at 1,250° to 1,300°, will give a cement passing specifications as in systems involving the same components, in general the greater the number of components contributing to a eutectic the lower will be the eutectic temperature, and in addition to the lime, alumina and silica, other oxides present as "impurities"—such as MgO, Fe_2O_3, Na_2O_3, Na_2O, and K_2O compounds—all play their parts.

Apparently, therefore, the constituents of perfectly burned Portland cement are $2CaO.SiO_2$, $3CaO.SiO_2$, and $3CaO.Al_2O_3$. The alite of earlier investigators was apparently a mixture of the latter two compounds, and celite was probably $2CaO.SiO_2$ or an intimate mixture of $2CaO.SiO_2$ and $3CaO.Al_2O_3$. In actual practice, free lime is usually present in small quantities, and is the constituent which must be blamed when a cement is not volume-constant. The compound $5CaO.3Al_2O_3$ may also be present, but is not at all harmful. Of the minor oxides, a portion of the Fe_2O_3 colours the compound $2CaO.SiO_2$; the remainder occurs as a reddish to black opaque isotropic flux which sometimes shows magnetic properties. Magnesia has been shown by the Bureau of Standards to replace the lime in the silicates and aluminate up to a certain concentration beyond which Spinel ($MgO.Al_2O_3$) and Monticellite ($MgO.CaO.SiO_2$ are formed. It was also noted that if properly burned, cement could contain 7–8 per cent. MgO without being affected deleteriously.[†]

The *hydration* of cement has been extensively studied. Le Chatelier ascribed the initial setting to the aluminate of lime in contact with water hydrating and hardening like plaster, according to the equation

$$3CaO.Al_2O_3 + 12H_2O = 3CaO.Al_2O_3.12H_2O$$

and the later hardening to the decomposition of a lime silicate which yields a hydrated monocalcic silicate crystallising in microscopic needles and calcium hydroxide crystallising in large hexagonal plates according to the equation

$$3CaO.SiO_2 + H_2O = CaO.SiO_2.2\tfrac{1}{2}H_2O + 2(CaO.H_2O).$$

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[*] *Journal Franklin Institute*, June, 1916.

[†] "Concrete-Cement Age," *O.M.S.*, September, 1914, pp. 706–10.

In the investigations of the Bureau of Standards the following compounds were synthesized and studied under various conditions of temperature and pressure of reacting water $3CaO.SiO_2$, Beta $2CaO.SiO_2$, Gamma $2CaO.SiO_2$, $CaO.SiO_2$, $3CaO.Al_2O_3$, $5CaO.3Al_2O_3$, and $CaO.Al_2O_3$, and it was found that, in the early stages of setting, the constituents of Portland cement of normal composition and manufacture in the order of their strength-conferring properties are : tricalcium silicate, tricalcium aluminate, and dicalcium silicate. With an excess of water, tricalcium aluminate hydrates, forming the compound $3CaO.Al_2O_3.xH_2O$, where x varies with the drying conditions. 5 : 3 calcium aluminate and monocalcium aluminate, on hydrating, split off amorphous hydrated alumina and form hydrated tricalcium aluminate. With a limited amount of water, such as is usually encountered in concrete structures, the crystallised compound does not form immediately, but separates from solution as an amorphous material which slowly changes to the crystallised compound. When the individual aluminate grains become coated with the amorphous hydrated aluminate further action proceeds with more or less difficulty. Tricalcium aluminate alone sets too rapidly and attains too little strength to be of any commercial value as a hydraulic cementing material.

The nature of the calcium hydroxide, formed by the hydration of free lime depends upon the fineness of the lime grains and on the burning temperature. With coarse lime grains and with highly burned lime the hydration produces a preponderance of crystallised calcium hydroxide, but with fine lime grains and with low-burned lime amorphous hydroxide is chiefly formed. Calciumhydroxide crystals are much more inactive chemically than the amorphous variety.

The hydration of the aluminates in limewater reveals the same compounds as in distilled water, but there seems to be some action resulting in a greater development of crystallised hydrated tricalcium aluminate.

The first effect of gypsum solution is to retard the formation of amorphous hydrated aluminates and keep the pores of the material open to the further penetration of water. Specimens hydrated in saturated gypsum solutions show the highest ignition-loss after six days. The products of hydration are the same as those with distilled water, with the exception of the additional formation of needles of $3CaO.Al_2O_3.3CaSO_4.xH_2O$. The formation of this compound is only incidental to the initial set, and not the cause of its retardation. Variation of the gypsum content above and below a certain definite concentration causes a decrease in the setting time. Tricalcium aluminate containing 10 per cent. of plaster gains practically no strength after twenty-four hours.

The initial set probably involves the action of small amounts of electrolytes in retarding the coagulation of the amorphous aluminate material. The evidence is in favour of the aluminates coagulating and separating as amorphous bodies from supersaturated solutions. Thus with a certain and definite concentration of gypsum, maximum hydration is attained, and at the same time the rate of coagulation is retarded, increasing the time of set.

Calcium metasilicate, as well as gamma-calcium orthosilicate, is practically inert with regard to hydration. Beta-calcium orthosilicate is but slightly hydrated in water, until after a considerable length of time ; it sets too slowly and attains strength too slowly to be of any commercial value when used alone, although at periods beyond twenty-eight days it gains sufficient strength to place it almost on an equality with tricalcium silicate. It, therefore, adds somewhat to the strength of the cement at later periods.

Homogeneous tricalcium silicate has not been obtained, the most satisfactory product containing an extremely small amount of free lime, beta-orthosilicate and tricalcium aluminate. Tricalcium silicate hydrates readily, forming crystals of calcium hydroxide and amorphous hydrated silicate. It sets hard in five hours, and possesses all the important properties of Portland cement. It shows no sign of disintegration after twenty-eight days in water and in the autoclave test. Mixing tricalcium silicate with beta-calcium orthosilicate has no favourable effect on the hydration of the latter.

In mixtures of tricalcium silicate and the aluminates gauged with water, limewater, and plaster solution, the hydration of the aluminate begins first, and is followed shortly after by the hydration of the silicate. Tricalcium aluminate when used to replace 19 per cent. of tricalcium silicate does not add to the strength of the latter, showing rather a tendency to decrease it at later periods.

The hydration of cements is thus brought about by the formation of amorphous hydrated tricalcium aluminate with or without amorphous alumina, the aluminate crystallising later. At the same time, sulpho-aluminate crystals are formed, and low-burned or finely ground lime is hydrated. The next compound to react is tricalcium silicate, whose hydration begins within twenty-four hours. Between seven and twenty-eight days the amorphous aluminate commences to crystallise and beta-orthosilicate begins to hydrate. Although the latter is the chief constituent of American Portland cements, it is the least reactive compound. The early strength (twenty-four hours) of cements is probably due to the hydration of free lime, the aluminates, and the beginning of tricalcium silicate hydration. The increase in strength between twenty-four hours and seven days depends chiefly upon the hydration of tricalcium silicate, and also on the further hydration of aluminates. The increase between seven and twenty-eight days is due to any further hydration of tricalcium silicate and to the beginning of hydration of beta-calcium orthosilicate, but it is partly counterbalanced by the hydration of any high-burned free lime and in the crystallisation of the aluminate. It is to this hydration that the falling off in strength between seven and twenty-eight days of very high-burned high-limed cements is due, whereas the decrease shown by the high-alumina cements is due to the crystallisation of the aluminate.

The dicalcium silicate hydrates to a very granular porous mass which is chemically more resistant to the actions of solutions than the tricalcium silicate, but furnishes a great number of voids in which salts may crystallise out of solution, and it offers very little resistance to the mechanical action of these salts.

On the other hand, the hydrated tricalcium silicate with its very dense structure, composed of colloidal silicate interspersed with crystals of lime hydrate, is probably very susceptible to strains produced by alternate wettings and dryings. Hence, the composition of Portland cement should be such as not to produce a great preponderance of either silicate, but it may possibly have an excess of dicalcium silicate, which would give a not too dense hydrated material, gaining strength at later periods. A lesser amount of the tricalcium silicate would furnish the desired early strength and also overcome the excessive porosity of the dicalcium silicate. The aluminate in the finished cement appears to be merely a diluent or inert material, although it plays an important *rôle* in lowering the temperature of formation of trisilicate when the clinker is burned.

Mr. G. A. RANKINE, of the Geophysical Laboratory, Washington, provided a paper which largely covered the same ground as Mr. Klein's, and in which the same conclusions were reached, though Mr. Rankine laid more stress on the part played by the gelatinous matter formed by the action of water on cement.

He regards tricalcium silicate as far and away the most important constituent of Portland cement and pointed out that it is probably the only compound containing silica in combination in such a manner that it is *readily* released to form a thin coating of gelatinous silica when mixed with water to form a mortar. At the present time an average Portland cement contains about 30 to 35 per cent. of tricalcic silicate, and to increase this percentage is a matter of considerable difficulty, as this silicate is chiefly formed by combination of lime and silica at a temperature of 1,700° C., which is too high for industrial practice. In order to produce it at a sufficiently low temperature to become a commercial possibility, it is essential to provide some low-melting flux to facilitate the combination of lime and silica. At present this flux is furnished by the low-melting calcium aluminates and the small amount of iron oxide and magnesia present in the clinker.

Although it does not appear commercially possible to increase the percentage of tricalcic silicate in Portland cement, there is another possibility, which may be more practical—namely, to readily release hydrous silica from some compound containing a higher percentage of silica than tricalcic silicate. Thus, dicalcic silicate, whilst practically inactive towards pure water, is appreciably hydrated in a solution of calcium aluminate. Some other solution or electrolyte may be found which will release hydrated silica from dicalcic silicate as readily as water now releases it from tricalcic silicate.

Mr. Rankine regards with favour the use in sea water of iron cements containing 7 to 8 per cent. of ferric oxide. He attributes the greater resistance to sea water of these cements to the formation of some chemical combination of the iron oxide with the calcium aluminates which resists the action of sea water. While the nature of this chemical combination is uncertain, it is known that the pure aluminates, particularly the compound $5CaO.3Al_2O_3$ when burned with about 5 per cent. of iron oxide, produce a clinker which when ground and mixed with water is sound and of good strength. A pat of this material, even when subjected to the action of steam for a long period of time, shows no sign of disintegrating.

In a paper by Mr. J. G. Rhodin, the suggestion is made that

the chemical composition of a cement may vary very considerably, but the physical condition, common to all cements, is a condition of labile molecular equilibrium. This liability may be so great that some cements lose their cementing properties *when stored in a stoppered bottle for twenty-four hours*, as in an actual case which he quoted. After a research lasting several years, the remedy was found to consist in adding 0·5 per cent. of aluminium sulphate or alum before firing. The addition of aluminium sulphate to the freshly burned cement does not improve its quality; it simply prevents it from reverting to inactive silicates. The curious part is that alum affects plaster in the same way, making Keen's cement store well and quick-setting, in contradistinction to German Estrich gyps, which stores badly and sets slowly.

Mr. Rhodin concludes that the molecules of a cement are in a state of tension, ready to break up into smaller centres similarly to colloids changing into crystalloids and that the speed of this breaking up can be diminished by adding substances acting in the reverse way to a catalyser. Arguments in favour of this conclusion are: (*a*) The fact that fusion spoils all cements, making glassy slags, which no amount of grinding will turn into cement; (*b*) the similarity of the behaviour of cements and zeolites; and (*c*) the constancy of volume of setting of sound cements. He regards the after hardening of cements as partly a continuation of the foregoing process, and partly a carbonating process, which, though very slow and gradual, is quite perceptible even after a year or more.

Prof. F. G. Donnan drew attention to the following four principal factors which tend to cause the agglomeration ("caking," binding, or setting) of granular masses of material. For this purpose the material must be immersed in a medium which exerts some solvent action, or the granules must be wetted with such a medium. A very small amount of such a solution will suffice:

1. *Unequally Distributed Stress.*—If the solid, but not the liquid, be subjected to compressive stress, the solubility will increase, and the additional material dissolved will be reprecipitated in contact with unstressed portions of the solid, and will cement them together by the formation of crystalline "bridges" of reprecipitated material. Gravitation suffices to produce the stress.

2. *Unequal Size of Granules.*—Very small particles have a higher solubility than larger ones, so that in a mass of granules of different sizes the layer of solution on the fine particles is not in equilibrium with the layer on a neighbouring large particle, and re-solution and precipitation (re-crystallisation) occur, cementing bridges are formed, and the mass sets.

3. *Existence of Unstable or Metastable Forms.*—At any given temperature and for any given solvent an unstable (metastable) crystalline form has a higher solubility than a more stable form. If the granular mass consists of a metastable form which is slowly changing into a more stable form so that a metastable and a stable particle in contact, re-solution occurs at the surface of the former and recrystallisation at the surface of the latter, cementing being produced as in the previous cases.

The setting of ordinary plaster of Paris is a well-known case of this kind which has been fully discussed by Le Chatelier. The reprecipitated (or recrystallised) material may be so finely granular as to be practically "colloidal."

4. *Sheared or "flowed" Crystal Surfaces* ("Beilby effect").—Owing to grinding or other shearing actions, the surface layers of some of the crystalline granules may

have become "amorphous," and will possess a higher solubility than the stable crystalline surfaces, tending, as in the previous cases, to produce recrystallisation and consequent agglomeration.

"The effect of the addition of slag on the setting properties of Portland cement" was stated by Messrs. E. DENY and E. H. LEWIS to be beneficial when a suitable slag was used in appropriate proportions.

The slag which they used was from blast furnaces in which hematite pig iron is manufactured; fairly high (49 per cent.) in lime, 39 per cent. of silica, 15 per cent. of alumina. The high lime content is due to the necessity of removing the sulphur from the pig iron.

Cement made from blast furnace slag is, of course, like other Portland cement, made from limestone and clay, except that it has been subject to a double burning, being first passed through the blast furnace. It also has a high alumina, silica ratio, and is usually quick-setting, but this can be adjusted by the use of a suitable limestone or the addition of granulated slag. These authors showed that experiments they had made on the addition of up to 30 per cent. of granulated slag to well-known brands of Portland cement regulated the setting time and added considerably to the tensile strength of the cement. They also called attention to the fact that, with their cement, the high content of alumina makes it possible, contrary to the generally accepted theory, to use without fear of expansion a greater percentage of lime in the clinker than is usual. The result of grinding such a clinker without any addition of raw slag is a very quick-setting cement; but if suitable slag be added the result is a cement of reasonable setting time, which soon attains so great a strength that it has reached 1,300 lb. per sq. in. at 28 days. They suggest that the quick-setting and quick-hardening are due to the colloid formed by the hydrolysis of the calcium aluminate and present to an unusual degree, having a favourable influence upon the subsequent formation of a colloid by the hydrolysis of the calcium silicate.

Finally, Mr. W. J. DIBDEN, in his paper on "Ancient and Modern Mortars," gave some information which is of value if applied to concrete, though no such application was made by the author.

Mr. Dibden suggested that a comparison of the proportion of lime to aggregate, a study of the nature of the aggregate, and on the influence of clay in it would be valuable, particularly if both ancient and newly-made synthetic mortars were compared. He explained that the ancient art of making mortar has not been lost, and that properly compounded modern mortars will, within a reasonable time, possess a strength equal to the best old samples obtainable.

He urged the necessity of being explicit when specifying the composition of mortars, particularly with regard to the form in which the lime exists when measured. It is not sufficiently recognised that the volume should always be stated in terms of *unslaked* lime, and in stating the results of analyses of mortar the volume of lime is calculated from the percentage of pure CaO on the assumption that the original lime was comparable to a commercial lime containing 80 per cent. CaO, and multiplying the weight so found by 2⅓, to convert it from *weight* to *volume*.

Investigations on twenty-six ancient mortars showed that, whilst the volume of aggregate to 1 volume of lime varied from 0·4 to 3·7, in only four instances out of twenty-six was it more than 2, the average of these being about 1, as compared with the modern practice of 3. Hence, the ancient mortars contained larger quantities of lime than is considered permissible in modern practice, on account of the cost of lime.

Modern specifications generally state that the aggregate is to be "clean, washed sand, etc.," but analyses of ancient mortars of the twelfth and thirteenth centuries, and that of the London Wall, show that the aggregate was largely that of gravelly sand with up to 19·5 per cent. of clean ferruginous clay.

In mortar from Allington Castle, early thirteenth century, the relative proportions of lime to sand, etc., in three samples were 1 to 1·7, 1 to 1·1, and 1 to 1·9, the percentage of clean ferruginous clay was respectively 8·6, 3·66, and 4 per cent. on the sand, which was fairly coarse, the proportions of coarse sand retained on a ¼-in. mesh being 20, 22 and 12 per cent. respectively. The crushing strength of the first of the three samples was 144 lb. per cu. in., and that of the second 90 lb. Two other samples from the same building contained lime in the proportions of 1 to 1 and 1 to 1·3; clean red clay in the proportion of 4·5 and 5·7 per cent. of the aggregate, respectively; the crushing strength being 162 lb. and 194 lb. per cu. in. respectively.

Two samples of Roman mortar—viz., from the Pharos, Dover, and a Roman villa at Darenth, contained clean lime and broken brick only; whilst another from Threlfall Castle, near Hythe, contained clean flint and pebbles for the aggregate.

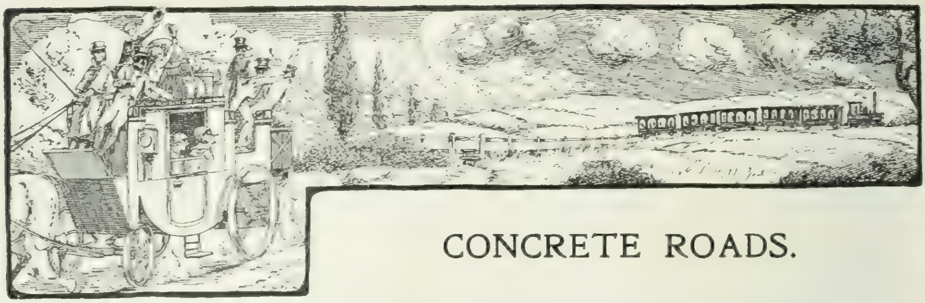
There was, therefore, no systematic method in the preparation of these early mortars, evidently materials most conveniently obtainable being employed, preference, however, being given to clean ferruginous clayey, gravelly sand when obtainable.

Results obtained with experimental samples of mortar made with known materials and tested after being kept for two years show distinctly the advantage gained by the early builders in fixing the ratio of lime to aggregate at about 1:2, and the use of a coarser aggregate. The modern rush after economy, by reducing the proportion of lime, is very largely responsible for the poorer quality of many modern mortars.

The presence of *clay* in the "sand grit," deserves special attention. Experiments made by the author showed that when the proportion of lime to aggregate is 1 to 3, clay is disadvantageous with white chalk lime and greystone lime, but with blue lias lime a marked improvement is obtained. Under other conditions, the use of clay is distinctly advantageous. For instance, the strength of blocks made of 1 volume of greystone lime and 5 volumes of Standard sand without clay was only 42 lb. per cu. in., whereas without clay blocks made of the same materials but after adding 7½ per cent. of clay to the sand had a crushing strength of 183 lb. per cu. in., and blocks made with 1 volume of lime and only 2 volumes of sand containing 10 per cent. of clay had a crushing strength of 223 lb. per cu. in. Similarly, 3 volumes of Lewisham fine sand and natural clay with 1 volume of lime had a crushing strength of 154 lb. per cu. in., but on using the same sand washed free from clay the crushing strength was reduced to 33 lb. per cu. in.

The proportion of voids or spaces between the particles of sand has an important influence on the strength of mortar. Thus, a mortar made with a sand having 40 per cent. of voids had a crushing strength of only 70 lb. per cu. in., whilst with a sand having only 23 per cent. of voids the crushing strength was 154 lb. Hence a larger proportion of lime should be used with coarse sand, a ratio of 1 to 2 giving far better results than a ratio of 1 to 3.

The suggestion that soluble silicates are formed in mortars in the course of time is not borne out in the author's experience, and his examination of numerous samples of ancient mortar revealed the presence of no more soluble silica than is normally found in ordinary fresh-made mortar—about 0·3 per cent. In those cases in which the soluble silica is higher, as at Pembrey Castle, Caermarthen (thirteenth century) where the soluble silica is as much as 2·95 per cent., and the core of the old wall at Crosby Hall, where 3·8 per cent. was found, the character of the mortar leads to the conclusion that trass, pozzuolan, or some equivalent material, had been employed.



CONCRETE ROADS.

Some interesting particulars regarding Concrete Roads in Canada and New Zealand have recently come to our notice, and we have pleasure in presenting this information to our readers in the subjoined article. For our details regarding the New Zealand roads we are indebted to the "Commonwealth Engineer."—ED.

The Toronto-Hamilton Highway.—This very important concrete road, which is thirty-five miles in length, and connects the cities of Toronto and Hamilton, with a combined population of 600,000, has recently been referred to in such glowing terms by Mr. H. S. Van Scoyoc, the Chief Engineer to the Toronto-Hamilton Commission, that we feel sure it will be of considerable interest to many of our readers to place before them some of the special features he has dealt with. The construction of the road began in November, 1914, and was officially opened three years later. As regards the traffic, he states that in 1917, with the five miles nearest Toronto not available to through traffic, a maximum count in one day registered 3,840 vehicles. Of these 3,065 were pleasure motors, 107 commercial motors, 148 pleasure horse-drawn, and 41 commercial horse-drawn. Probably a conservative estimate places the maximum daily traffic during the present year at 6,000 vehicles. These figures undoubtedly afford testimony of the great popularity of the road. Probably no other surface approaches the wood-floated surface of a concrete roadway in affording safety for motor traffic. It provides a satisfactory foothold for horse-drawn traffic and offers the least resistance to traffic of any known surface. For this reason there is a decreasing tendency to cover it with any other material until years of service make this desirable.

At the official opening the Honourable Mr. Duffy, Commissioner of Highways for the State of New York, in an address delivered on that occasion, stated: "It is the finest constructed road I have ever seen, and it is made of the finest possible material that we know of."

With reference to the maintenance cost of this road, we are informed that during 1917 on 312,100 square yards of concrete (approximately thirty miles) the sum of $767·70 was spent, or, roughly, one-quarter of a cent per square yard. This is so eminently satisfactory when compared with the well-known and frequent costly upkeep of macadam that one is at a loss to understand why roads of this description are not more frequently laid in this country. That they will be to a large extent the roads of the future there can be little doubt. In the meantime there is the question of prejudice, the idea of an innovation, the fear of taking any risk—not that there is much cause for this—all of which is very conservative and Englishlike, but in time will surely disappear, and signs are not wanting that when the opportunity arises, and money can be spent, concrete roads will be given the fair and thorough trial they deserve. It is a curious fact that some of the most direct opposition to the concrete road has emanated from those who imagine that a highway of this character is going to do away with the use of any bituminous surfacing. However that may be, time and experience will alone show. It certainly seems highly probable that our engineers, road surveyors, and road contractors will have to adapt themselves to an altered condition of things. The making of a good concrete road requires proper material and careful supervision during its construction: but, once laid and given the necessary time for setting—at least three weeks before traffic is put on it—there can be no doubt of obtaining a sound and perfect road, and one which is going to cost but a trifling amount to the taxpayer for its upkeep.

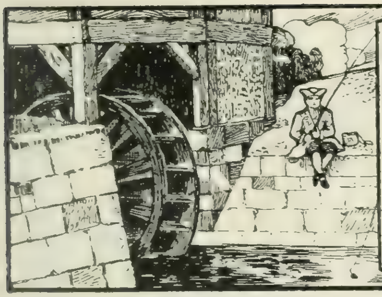
All this and more has been made so evident in America and Canada, where concrete roads are ever on the increase, that we readily pay a tribute to the motto published in the *Concrete Highway Magazine*, which is: "Concrete for Permanence." The same interesting little brochure adds:—"Our work in the New Year and in the years to come: To build, to set our hands to constructive effort along our highways, to the end that our engineering knowledge may be used for the benefit of our fellow-men, and to the honour and glory of Our Country. Ours is the duty of paving the way permanently for the economic transport of our nation's products, of effecting a saving through permanent construction where waste and neglect now rule, of quickening delivery of supplies throughout the land and hastening military movement in this momentous hour. We are called to duty upon our highways at a period in which our just reward is in proportion to the degree of lasting service rendered in the building of time-saving, power-saving roads. Rejoicing in the fact that to us has been given the task of building at a time when permanence is needed most, we accept the call, pledging ourselves to think less of self and more of our flag, and to press on with renewed zeal for the advancement and security of our country in supplying its most vital need—the open, durable road."

New Roads in New Zealand.—Three concrete roads have been constructed by the Auckland City Council—viz.: in Lower Queen Street, Durham Street West, and in Park Road. Regarding the two first mentioned, they are completely successful, but that in Park Road is not so satisfactory. There were certainly unavoidable circumstances which gave specific reasons for the difficulties that arose in connection with the latter. First, the weather was very cold and wet during most of the time the road was under construction, and as a consequence the heavy rain storms prejudicially affected the concrete whilst setting. The proper shingle for the aggregate was not readily obtainable, and finally that portion of the road, the northern end, where the trouble arose, had to carry traffic too soon to give it a chance. The southern section of the road subsequently done stood up to the traffic well. Under conditions such as described it is not surprising that trouble occurred.

Mr. W. E. Bush, the City Engineer, last October dealt fully with the details which had contributed to such a result, but his last statement on this subject is self-evident of his strong advocacy for concrete roads. He says: "The success of the concrete road means a great deal not only to Auckland, but also to other cities similarly situated in regard to climatic conditions, as it can be put down for half the cost of an asphalt-paved or wood-block road, and so far there is every indication that its adoption by the City Council is fully justified."

Concrete Road near Gravesend, Kent.—As is generally well known, a certain section of the London to Dover main road was laid in concrete by way of experiment towards the end of 1914 and opened for traffic the following March. It is unnecessary to refer in detail to the specification which governed the making of this important highway. Suffice it to say that on one half of the road the proportion of aggregate to cement used in the surface to a depth of 1½ to 2 in. was altered to 3 to 1 instead of 6 to 1, as was the case on the other side. Mr. H. S. Chapman, County Surveyor of Kent, in his last year's report to the Bridges and Roads Committee of that county, said: "Two and a half years have now elapsed since the work was completed, and the portions surfaced with 3 to 1 concrete are practically as good as when finished." The road carries a heavy and damaging type of traffic, considerably over 1,000 tons per day. It has now had a life of three years; the surface is still thoroughly sound and good. It has not been tarred, and in fact not a penny has been spent in the way of maintenance upon it. Surely this is an object lesson well worthy of close consideration by road surveyors and municipal bodies.

The Roads Improvement Association, of 15, Dartmouth Street, Westminster, have issued an interesting report of the present position and possible future of concrete roads in this country. It is written by Mr. H. Percy Boulnois, M.I.C.E., etc. We have already drawn attention to this brochure, but inasmuch as it contains a splendid guiding specification for concrete road construction we have no hesitation in again calling our readers' attention to it.



CHALK AND CEMENT BUILDING BLOCKS.

In our last issue we made reference to the use of chalk as an aggregate in concrete, and the following particulars of some buildings erected of chalk and cement blocks may interest many of our readers.—ED.

An extremely interesting method of making a most useful block or brick for the rapid and economic erection of structures of a light yet permanent character has been introduced by Capt. A. T. O. Quick, R.E., and has, we understand, been patented. The primary object of his design is to produce quickly and economically buildings of bricks and standards made from a composition of Portland cement and chalk in the proportion of one of the former to four of the latter. The dimensions of the bricks are 10 in. by 10 in. by 2 in., through which extend open-ended passages, so that the brick substantially consists of two walls at a distance apart united at the ends and intermedially by webs. They are built up in bays 11 ft. 9 in. between columns, which are 8 in. by 8 in. in section reinforced by four strands of $\frac{1}{4}$-in. iron. The foundations are of cement and chalk made up in the same proportion as the bricks and well rammed. The bricks for walls are made in moulds of ten to a mould. The chalk is crushed to a powder and the Portland cement mixed with it until it is reduced to a slurry condition, when it is poured into the moulds and allowed to set. Care must be taken to ensure that no air spaces are formed in webs of bricks. A damp course is provided by two layers of ruberoid, the bottom course being solid bricks. The roof covering is of ruberoid and canvas on suitable light wooden frames in panels, thus using a minimum amount of timber. The floor can be either wood or chalk concrete as desired; if of wood, the floor is so arranged as to be quite independent in order to minimise the effects of vibration on walls.

This type of building provides useful accommodation for barrack huts, hospitals, stores, and workshops, and by extending it laterally the grooved columns allow spaces to be partitioned off as desired. The buildings are free from damp and draughts, fire-resisting, and very clean. It is stated that a building 72 ft. by 16 ft. can be erected complete in five days, and at the present price of materials works out at a quarter the cost of a similar construction made of wood and iron.

That a very marked success has been obtained by Capt. Quick will be seen on reference to the photographs of some of the buildings which he has erected in France, and which, together with the plan, fully illustrate the fact that the practical utility of the chalk brick has already been placed beyond the region of experiment.

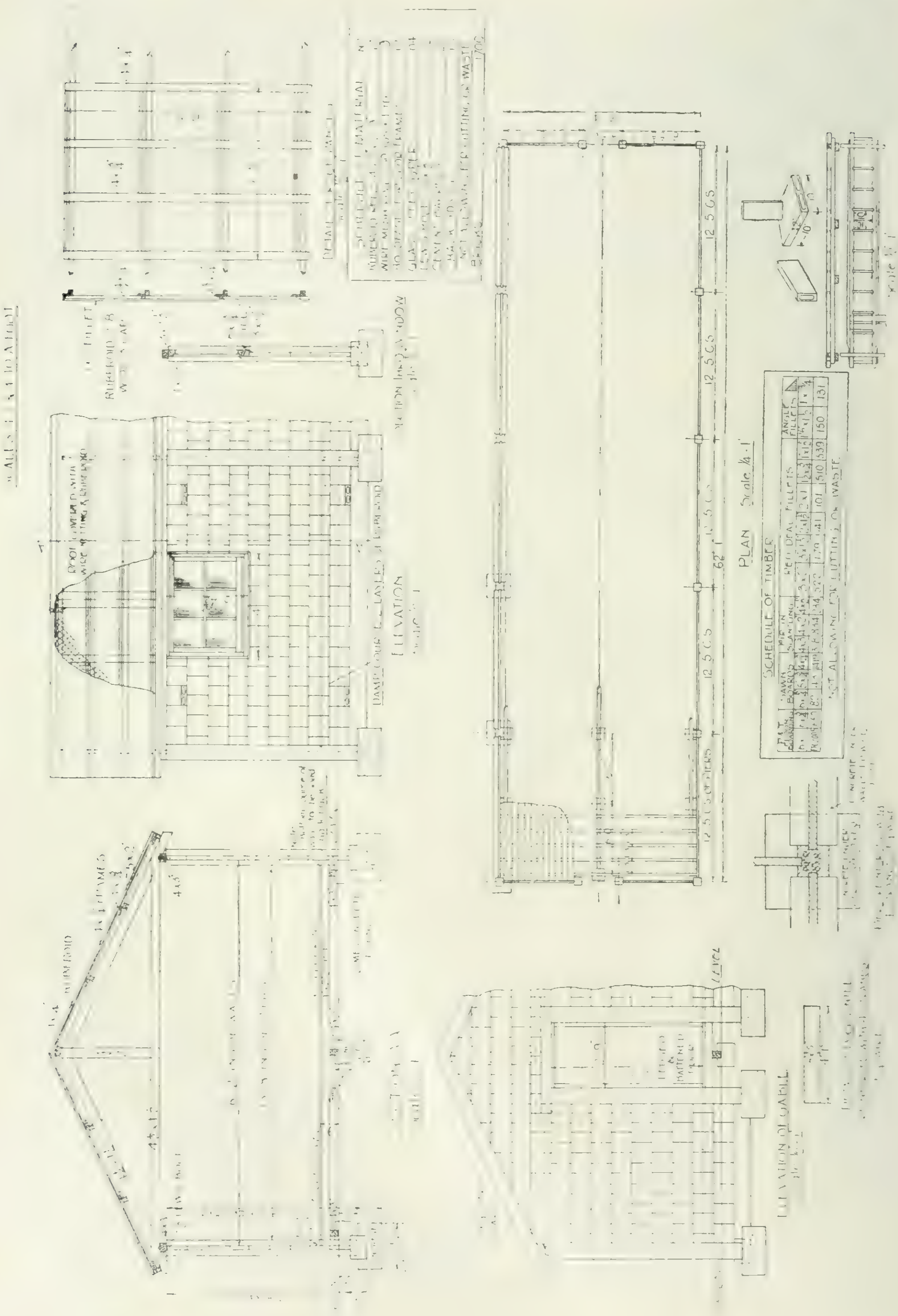
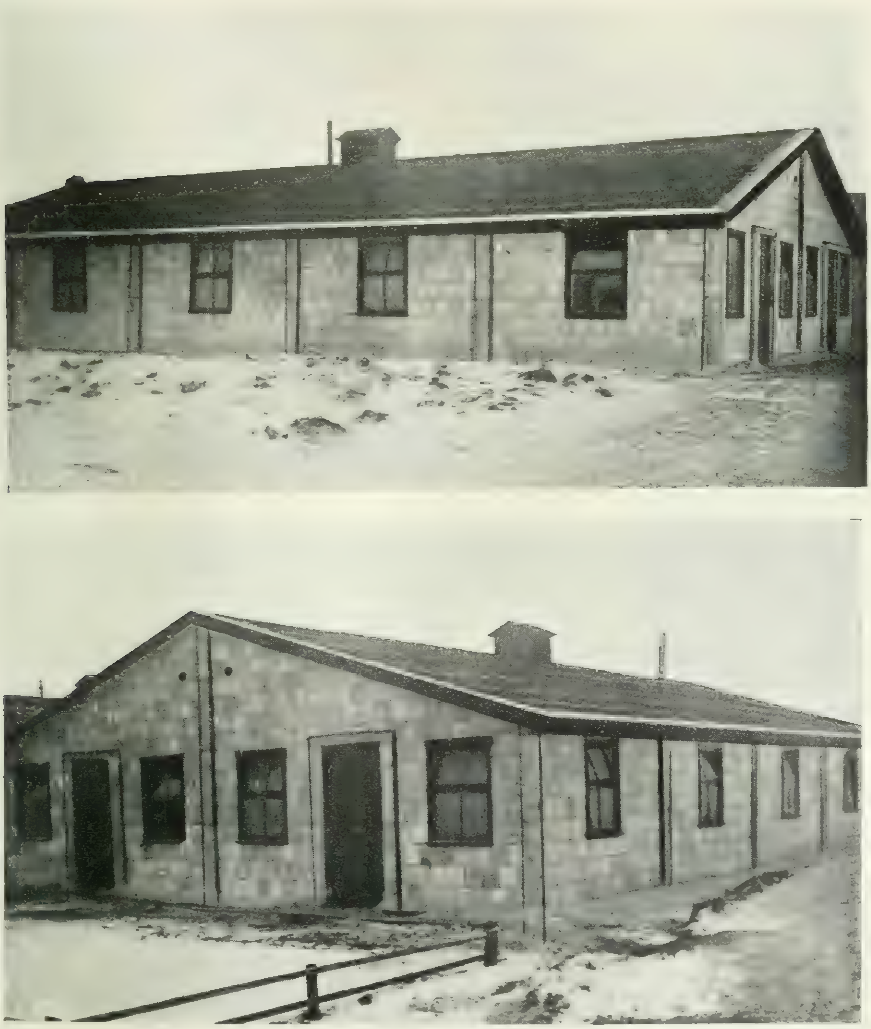


FIG. 1.—DETAILS OF NEW STANDARD TYPE OF CHALK CONCRETE BLOCK HUT.

In these days concrete is playing such an ever-increasing part as a sound and reliable substitute for a vast number of old-time building materials, therefore it is more than interesting to record the introduction of the "Quick Block." We are informed they have stood well the severe weather conditions of the winter and that the buildings erected with these blocks are much appreciated by those who live in them, being warm and dry.



FIGS. 2 & 3. GENERAL VIEW OF COMPLETED BUILDINGS.

From the foregoing ample evidence is given that even with such an aggregate as powdered chalk, which many would have discarded as useless, if mixed in the right proportions with Portland cement, a very useful concrete, suitable under certain conditions, can be made for the class of work referred to.

CONCRETE COTTAGES.

A Book Review.

The Book that has recently appeared under the title "Concrete Cottages" is a valuable contribution to the present-day discussion of the Housing Problem.—ED.

THIS book has been prepared and published for the purpose of giving useful and reliable information as to the use of concrete for cottages and other small buildings. The problem of the cheap and well-built cottage is daily becoming more pressing, while the use of concrete is becoming more extensive, and there is no doubt that considerable scope exists for the use of this material in cottage work if its possibilities are thoroughly understood.

The first chapter of this volume deals with the application of the various types of concrete construction to cottages generally, and the methods to be employed and the merits of the different types are discussed. Notes are given on the construction of walls, floors, roofs, staircases, sills, doorsteps, lintels, and getterings, with diagrams showing the different parts, and illustrations are introduced of actual cottages which have been erected wherein such construction occurs. A small section is devoted to the important question of labour-saving devices, as this must not be overlooked in the planning and equipment of the modern cottage.

The second chapter shows how concrete can be successfully applied to different classes of small buildings other than cottages, including small garages, cowhouses, stables, barns, and farm buildings generally, and illustrations are given of work that has been executed with the material.

As the volume is essentially a practical one, and intended for the use of builders as well as estate owners and architects, a chapter is introduced which gives some general information on the execution of the work both in the yard and on the site. Block-making is described in detail as being one of the most important sections of the work, and the questions of plant, supervision, and organisation are dealt with.

A special chapter is devoted to designs for cottages, many of these being examples which have been actually erected, while the remainder show the plans and sections of buildings which have been specially prepared for execution in concrete, and these should prove very useful to those who have not had previous experience in this class of work.

Concrete tiles and fence-posts have become an important section of concrete manufacture, and the last chapter gives a detailed description of the manner in which such articles are made, the matter including the different kinds of roofing and flooring tiles—among the latter being concrete mosaic tiles—and all the types of fence-posts in general use.

The book is well illustrated throughout with drawings and photographs, and it is hoped that it will be of service to the large number of persons who are interested in the erection of cottages and other small buildings, as it deals with the class of work and the material which are daily becoming more important.

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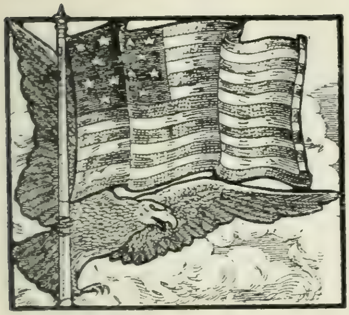
* *Concrete Cottages, Small Garages, and Farm Buildings.* Edited by Albert Lakeman, M.S.A., M.C.I. London: Concrete Publications, Ltd., 4, Catherine Street, Aldwych, W.C. 170 pp.+xii. Price 5s. net.



CONCRETE IN SEA WATER.

II

Continued from last issue.—ED.

Unreinforced concrete structures are subject to disintegration by the action of sea water irrespective of location. Unmistakable evidences of deterioration have been observed upon structures along all the coasts of the United States as well as those of Canada, Cuba, and European countries. As a rule, the failure of a concrete structure in sea water has been explained on the ground that the concrete has been of poor quality. It is a fact that wrong design, poor materials, and improper methods of construction will often lead to rapid disintegration, but even the best of concrete will be chemically attacked after the surface has been appreciably abraded. In addition to the chemical disintegration which occurs to both plain and reinforced concrete if abraded then occurs a quite distinct physical deterioration of reinforced concrete due to the corrosion of the embedded metal. This will be discussed in a subsequent article.

Deterioration of plain concrete may be due to several causes, but the underlying one, which is chemical disintegration, cannot take place unless the original surface of the concrete as moulded is first abraded or eroded from mechanical means.

WHY CONCRETE IS ATTACKED BY SEA WATER.

One of the main constituents of cement is lime. When the green concrete is placed in the forms the lime of the cement at or near the surface is in a form to combine readily with carbon dioxide in the atmosphere. Thus there is formed at the surface and for a slight depth in the mass lime carbonate (limestone), which is practically insoluble in sea water. This layer or skin of insoluble material acts as an armour or protection to uncarbonated cement in the interior of the mass. If concrete is deposited in water it is not exposed to the air, but there is sufficient carbon dioxide in the water to carbonate the lime at the surface, and the same result is obtained.

If this is true, why does not the lime of the cement in the interior of the concrete carbonate in a similar manner when exposed, due to accidental abrasion of the surface? The reason is that as cement hydrates over a period of months in the interior of a mass of concrete where not exposed to carbon dioxide, the lime which is freed as the cement ages is changing from the amorphous to the large crystalline form. On account of its relatively slower rate of solution in water than amorphous lime this crystalline form, which is a hydroxide, does not react appreciably with the limited amount of carbon dioxide present. When the sea water comes in contact with the lime in its crystalline form the lime is dissolved and passes into solution largely as calcium sulphate, the magnesium salts of the sea water being precipitated as magnesium hydroxide, which is practically insoluble. The dissolving of the uncarbonated lime will continue until the cement is completely disintegrated.

Analysis of disintegrated concrete shows the lime content to be very much reduced and the magnesia content increased. When concrete is placed in sea water some magnesium hydroxide is precipitated on the surface. This coating may become very hard in time, and if not abraded act as a further protection to the concrete.

OUTER SKIN MUST BE PROTECTED AGAINST ABRASION.

Assuming this explanation to be true—and it is supported by the physical, chemical, and microscopic studies which have been made—it is quite evident that if the outer skin can be protected against mechanical abrasion the permanency of the structure is assured against chemical disintegration.

This chemical action, therefore, is not confined to any particular locality, but occurs in the tropics as well as in the cold climates. The action is far more rapid in the latter case owing largely to the mechanical erosion from frost. Generally in warm waters the action is so retarded, especially if the quality of the concrete is good, that no apprehension should be felt. The disintegration proceeds at a very slow rate where there is no frost or severe mechanical erosion to remove the softened material.

There is a concrete sea wall on the Pacific Coast in a locality where the winter climate is very mild which serves as an excellent example. This wall, shown in *Fig.* 3, was built about seven years ago. The top of the wall is 18 ft. above mean low water, but one short section was depressed so that car barges can dock.

Some time after the completion of the wall it was found that the depressed section was about 12 in. too high, and a layer of concrete of this thickness was removed, leaving an abraded surface which is covered at half-tide. This surface has softened to a depth of ½ in., but the vertical front face of the wall just below the abraded surface is hard and in perfect condition; in fact, this surface which was cut away is the only part of the wall which shows any signs of chemical action. As there is very little wave action and no ice in this locality the disintegration is slow, for the softened material is not rapidly removed, and a fresh surface is not continually exposed.

The characteristic softened and laminated condition due to chemical action was observed in other localities along southern coasts.

FREEZING WATER ACCELERATES DECAY.

In northern latitudes where the concrete surface is abraded by ice in addition to the action of waves, vessels, and floating *débris*, and where the water freezing in the pores removes the decomposed surface so that fresh cement is constantly exposed to sea water, the chemical disintegration is

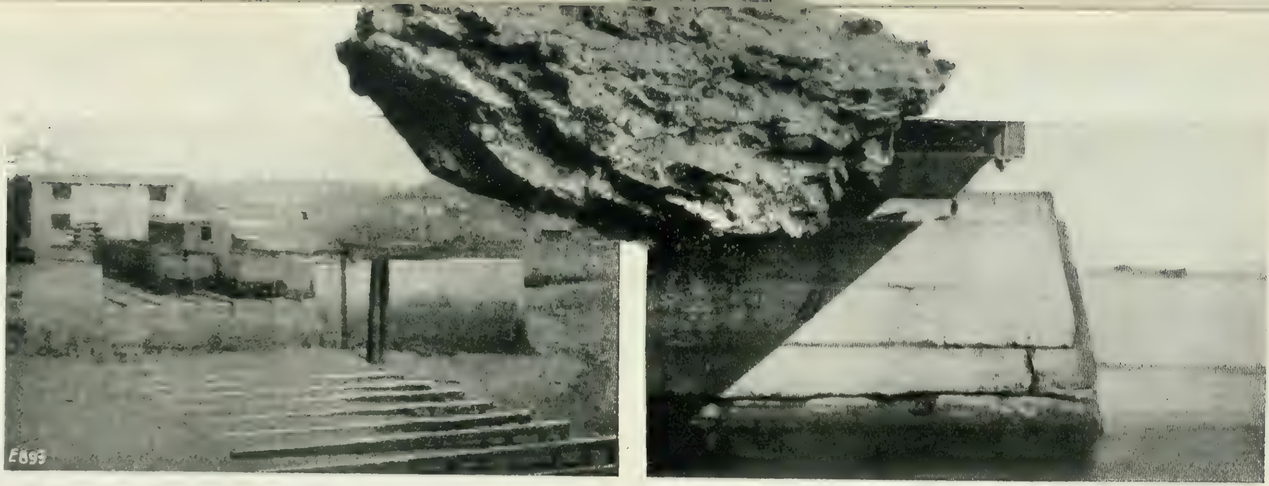


Fig. 3. Abraded surface is softening from chemical action of sea water.

Fig. 5. Erosion started at Construction Seams between successive days' work.

Fig. 4. Specimen of disintegrated concrete.

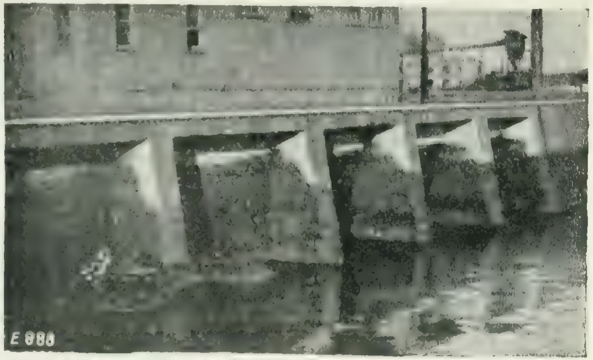


Fig. 6. Exposed Buttresses increased possibility of chipping and abrasion.

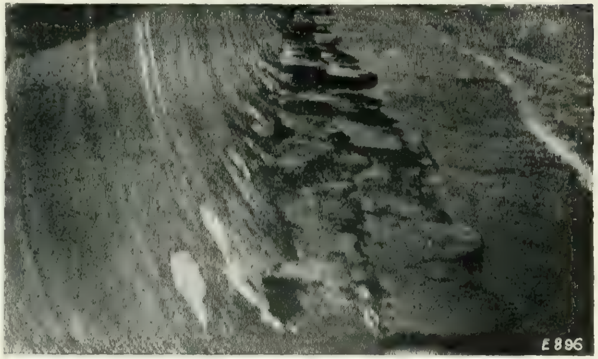


Fig. 7. Toe of wall rapidly disintegrating after sharp corner was abraded.

CONCRETE IN SEA WATER

accelerated and proceeds at a rapid rate if the outer skin has been destroyed. When concrete is acted upon chemically by sea water there is a typical lamination and softening of the mortar, so that the coarse aggregate can be removed easily.

Fig. 4 is a photograph of a specimen of disintegrated concrete removed from a sea wall which had been exposed to sea-water action. The loosened aggregate and laminated condition is typical. The mortar becomes like so much soft putty or clay containing grit. As soon as the outer skin is abraded even to a slight depth the disintegration starts, and it will spread from a softened section under the hard surface skin of the adjoining sound concrete. Where this has occurred the outer layer can be picked off with the fingers, and while the surface which was most exposed is hard and secure, the underside is softened owing to the disintegration progressing from an adjoining affected section.

It is obvious that if chemical disintegration does not occur unless preceded by mechanical erosion deterioration will generally be confined to those parts of the structure above the elevation of low water. The concrete below water is practically immune from attack unless it has been placed carelessly or unless the forms leaked to such an extent that loose stone pockets were formed. In such cases the scouring action of the current may soon undercut the concrete. There are a number of structures which have settled and cracked from this cause.

Concrete bulkhead walls have been built in New York Harbour at various periods from 1879 to the present. The construction consists of massive blocks which are entirely submerged. The exposed section of the wall is of granite. In 1912, due to some alteration, several blocks which had been placed in 1902 were removed. The concrete showed no signs of deterioration. Here is excellent evidence that the disintegrating action of sea water does not normally occur below low water.

Concrete structures which are subjected to sea-water action must usually be built where there is a rising and falling tide. The common practice has been to place the concrete below low water in a cofferdam or by means of a bottom-dump bucket or tremie. The concrete above the elevation of low water is placed in forms which are usually not watertight. When the water drops to the lowest elevation the work of depositing the concrete is started and carried up as fast as possible. Usually the tide rises faster than the concrete can be brought up, and when the water reaches the elevation of the uncompleted section the placing of concrete is discontinued until the tide falls again below this point. When the water recedes there is always found a layer of soft chalky material covering the top surface of the concrete.

LAITANCE COMES FROM TWO SOURCES.

This soft material comes from two sources. Part of it is cement, some of which rises to the surface of the concrete when an excessive amount of water has been used in mixing, and part of it is magnesia which has been precipitated from the sea water during submersion. The relative amounts of these constituents and the thickness of the layer are dependent upon a number of factors, such as consistency used, exposure conditions, methods of placing concrete,

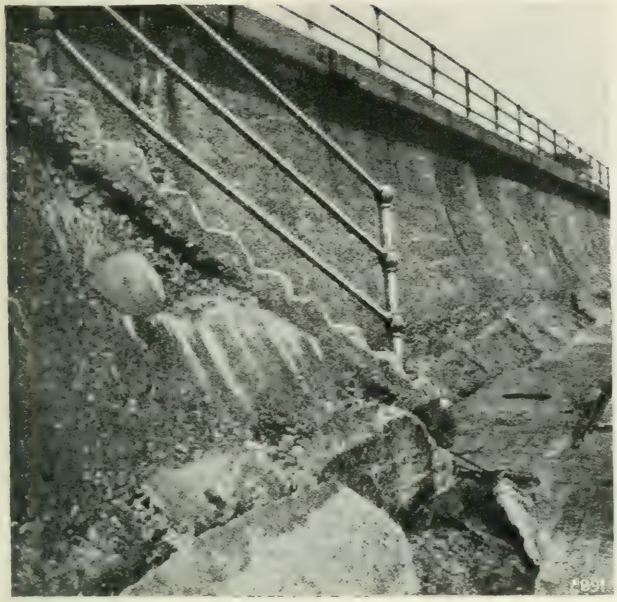


Fig. 8. Surface tooled off for artistic effect.

and fineness of cement. If the surface is not thoroughly cleaned of this soft material before the placing of the concrete is resumed a seam is formed. Such a condition is seen in *Fig.* 5. In a very large number of the concrete structures along our coasts these seams exist, and often they are 2 in. or more thick.

This soft layer is particularly susceptible to attack by abrasive action, and as soon as it is removed to even a light depth the adjoining surfaces of the concrete are exposed to the chemical action of the sea water. As a consequence disintegration very frequently begins at one of these construction seams.

The methods to be used to insure the stability of unreinforced concrete in sea water are dependent upon local conditions, but there are a number of principles of general application which should be followed. The design of the structure should be such that it will as far as possible offer the least opportunity for abrasion or erosion. Sharp corners and edges should be avoided, for these chip easily. An example of poor design from this standpoint is shown in *Fig.* 6. A pier structure with successive arches is defective in that a large surface is unnecessarily exposed to abrasion and chemical attack where most vulnerable. This could be obviated by either raising the arch so that the springing line would be above high

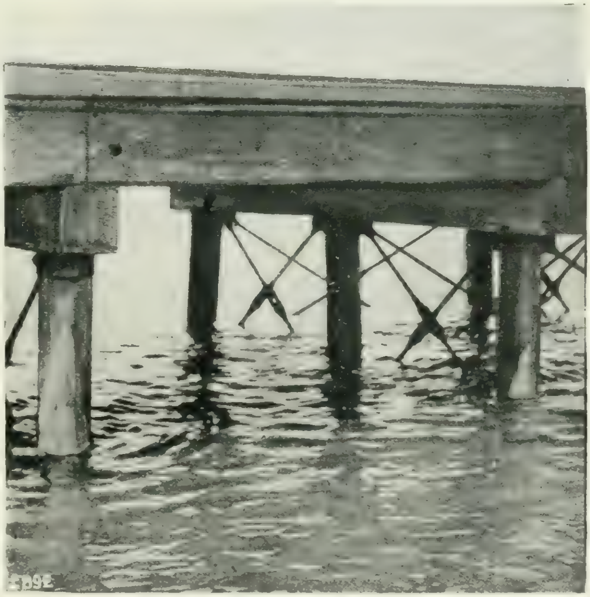


Fig. 9. Round Piles, not easily abraded.

water or lowering it so that the soffit at crown would be below low water. If neither is possible some other design should be employed. An adequate fender system which would prevent floating material getting under the arch would aid greatly in preserving the structure if the design is used.

The toe of the wall shown in *Fig.* 7 has sloughed off at the edges and the concrete has softened. The abrasion at this point was followed by chemical disintegration, which in turn made the softened concrete more easily abraded. Much of this would have been avoided if the exposed edges had been rounded.

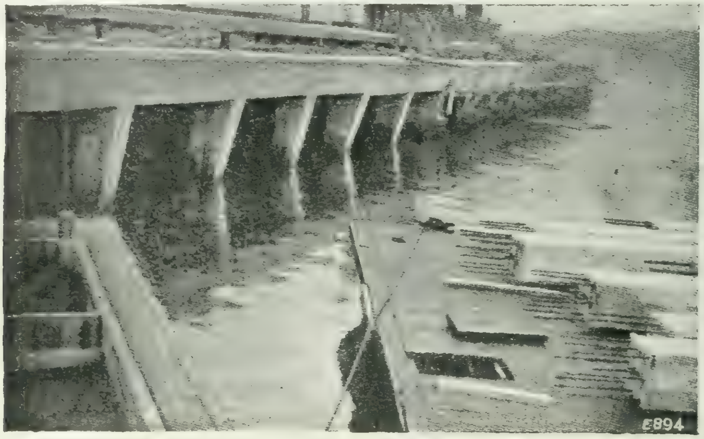


Fig. 10. Showing abrasion on square piles.

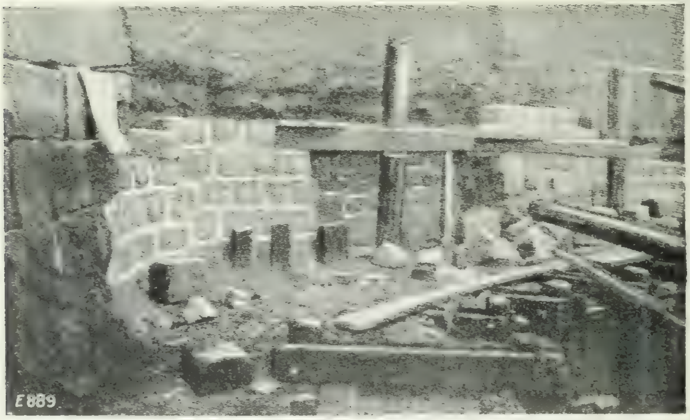


Fig. 11. Granite Block facing as protection to eroded concrete.
Concrete in Sea Water.

The sea wall shown in *Fig.* 8 was given special surface treatment, which resulted in starting chemical disintegration. In order to give an artistic appearance to this wall the surface was tool dressed. This of course removed the outer skin, and as a result softening of the concrete occurred within a very few years after the work was completed. Such practice should be avoided, for the most invulnerable part of the structure is destroyed as far as its resistance to chemical action by sea water is concerned.

The piles used in the wharf shown in *Fig.* 9 are of excellent design to resist abrasion. The round shape affords less possibility of chipping than any other. Even round piles, however, may be abraded by vessels or floating fender logs rubbing against them.

Ice floating on the surface of the water frequently causes chipping of such piles, and a good example of this was seen under one of the pleasure piers on the New Jersey coast. During a severe winter considerable ice formed and the waves and current threw it against the piles with sufficient force to cut the surface. The piles were round in this case, which probably minimised the action. Where the outer skin was removed the concrete beneath softened. A jacket of metal or creosoted wood covering the piles between high and low water would have afforded excellent protection and prevented the trouble.

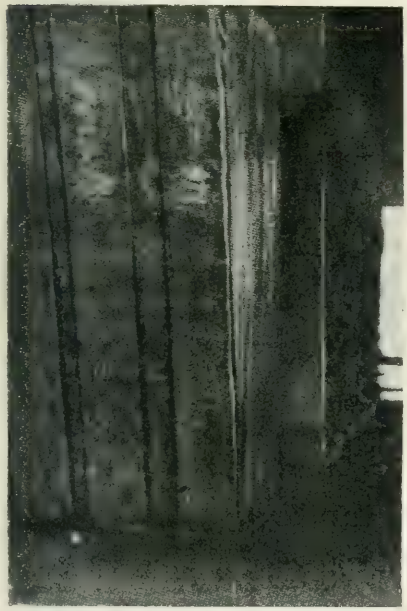


Fig. 12. Wood jackets used to protect piles.

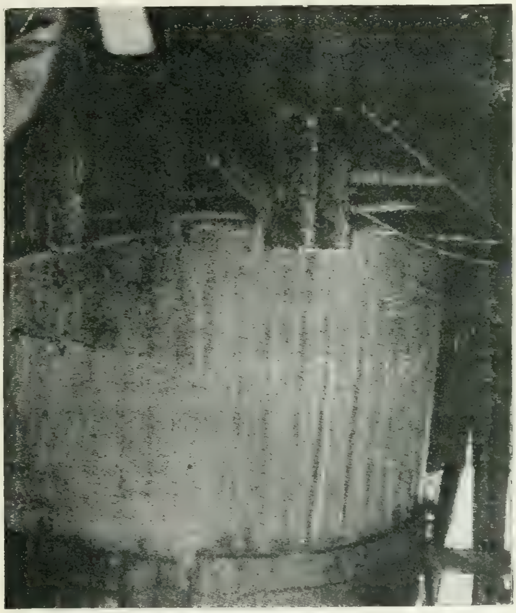


Fig. 13. Wood casing around pier to prevent deterioration.

Concrete in Sea Water.

There is a concrete sea wall on the middle Atlantic coast which offered an interesting study of the comparative effect of sea water on protected and unprotected sections. This wall extends at an angle into the harbour, and near the outer end is a wooden-pile wharf which covers part of the wall. The piles serve as an excellent fender, preventing any abrasive action on the part of the wall they cover. During the winter months there is considerable ice in this harbour, and the unprotected part of the wall has been deeply cut and the concrete disintegrated to such an extent that frequent repairs have been necessary. The protected section has not been injured in the slightest degree.

A Canadian engineer's early appreciation of the need of protecting his concrete wharfs against abrasion from ice saved much future trouble for himself and prevented loss to the owners. The wharf is in a harbour where during the winter months considerable ice forms. Square concrete piles were used, as shown in *Fig.* 10. After the first winter it was found that the surface of many of the piles was eroded, and where this occurred the cement had softened. Wood jackets were at once placed around the piles. These jackets extended from below the low-water line to the top of the pile and prevented any further erosion of the concrete. As can be seen from the view shown in *Fig.* 12, the wood jackets are being frayed, especially at the corners, but these can be easily replaced at comparatively small cost.

PROTECTIVE COVERS PREVENT DESTRUCTION.

Well made concrete when properly protected from abrasion will resist the disintegrating action of sea water even in localities where the winters are severe. In 1889 a number of large concrete bridge piers were built along the Bay of Fundy in connection with the construction of the Dominion Atlantic Railway. The tide rises 29 ft. or more and there is a very rapid current. There is not a great deal of ice on the water, as no fresh water tributaries of consequence empty into the bay near these structures. What ice and floating *débris* there is, however, strikes the piers with considerable force. The engineer who built these piers felt that it would be wise to protect the concrete from abrasion, especially those in the most exposed position. He used wood sheathing held in place with iron hoops. In 1914 an examination was made of these piers. The wood sheathing was completely removed from one of the piers and the concrete, as shown in *Fig.* 13, was found in perfect condition. There were no signs of softening, and the form marks were still visible on the surface.

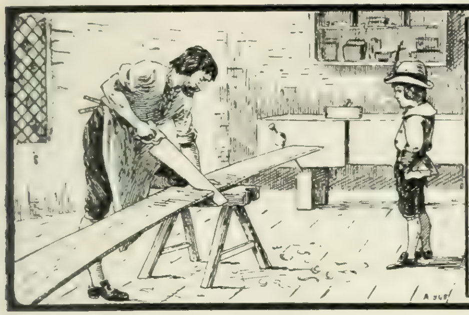
Along our New England coast the conditions of exposure are very severe. There is heavy wave action in many localities, and concrete walls are often called upon to withstand the shock from boulders thrown up by the sea. Frequently marine structures are located near where fresh water streams empty into the bay. As a consequence large quantities of ice abrade the surface of the concrete, and this, together with the water freezing in the pores, causes rapid deterioration.

Where such rigorous conditions exist it is advisable to protect the concrete with a granite facing if permanency is to be insured. This has been done in a number of instances with successful results. In this locality repairs can usually be made best by this method. The sea wall shown in *Fig.* 11 was badly undercut after a few years of exposure, and a granite block facing was used to restore it. In this instance the original concrete was of poor quality, for methods of construction were followed which will not give satisfactory results for marine work.

The conditions which concrete structures in sea water are called upon to resist are most severe, and only concrete of the best quality placed with the utmost care should be used. If this is done and the concrete is properly protected by adequate fender systems, a permanent structure can be secured.

To sum up the subject in a few words, well made concrete properly placed, if not subjected to mechanical abrasion or erosion, is permanent in sea water. If the structure is so located that the concrete would under natural conditions be exposed to mechanical abrasion, chemical disintegration can be prevented only by the provision of a fender system or other protecting medium. Disintegration by chemical action will be very slow unless there is frost action or appreciable mechanical abrasion continually to remove the decomposed cement products as they are formed.

(To be continued.)



CONCRETE SIMPLIFIED.

By THOMAS POTTER.

A Practical Guide to the General Use of Concrete.

(*Continued*)

We would again call the attention of our readers to this series of articles, publishea specially for those who wish to employ concrete for the many articles needed on the farm, the estate, in the garden, etc., and for which concrete is so admirably adapted, although its possibilities in this direction have not been fully realised in this country.—ED.

III.

GRADING THE AGGREGATE.

The size of the aggregate is an important feature in connection with the density of the concrete, and as a result in its strength and impermeability. It is scarcely feasible to expect equal density with a coarse aggregate in 6-in. and 12-in. walls respectively. In the former there is insufficient space between the enclosing boards or forms for the smaller portions to slide into place and interlock with the larger, as there would be in the latter. The London County Council in their regulations make no distinction in this respect, but say: "The concrete shall be composed of one part of cement, two parts of sand of a sharp, siliceous nature, and four of coarse material," the cement being increased where the requisite resistance or pressure exceeds certain limits, and that the coarse material shall pass a $\frac{3}{4}$-in. square mesh and the fine remain on a $\frac{3}{16}$-in mesh. If these conditions were made to apply to country districts they would prevent much concrete building. Sand of this description is only obtainable in neighbourhoods few and far between, and where the haulage would be considerable and the cost as well.

To eliminate the aggregate that would not pass a $\frac{3}{4}$-in. mesh would mean in most cases a large percentage of waste. The addition of sand, in my experience, is unnecessary; all the aggregates named either contain sufficient sandy size particles in their natural state or, if crushed, the crusher can be set to produce sufficient. I have never yet found occasion to add sand, nor have done unless it was specified. If an aggregate is of a suitable nature to make good concrete and to combine with lime or cement the sand size element must be equally as suitable. That from boiler ashes, slag, or brick *débris*, if washed and the fine portions eliminated, makes cement mortar stronger than most pit or river sands. Where, however, the sandy element in the aggregate is absent it is necessary to add sufficient to secure density, but bearing in mind that the greater the volume of sand the weaker the cement mortar.

My usual practice has been to grade the aggregate for 12-in. walls and over from 2 in. down to coarse sand size, 9-in. walls $1\frac{1}{2}$ in., and under 9 in. an inch or $\frac{3}{4}$ in. to coarse sand size, and walls built from this formula have invariably been weatherproof, and density must therefore have been attained.

Mr. Feret, an American engineer, read a paper on "Concrete" before the American Society of Engineers, and which was published in their *Proceedings*, Vol. XXXIII., and said: "To obtain the greatest strength it is advisable to increase as much as possible the size of the aggregate and diminish the finer grains. The largest aggregate makes the densest concrete. An aggregate with a maximum diameter of $2\frac{1}{4}$ in. proved to be denser than an aggregate of 1-in. maximum diameter. Permeability is less as the maximum size of the aggregate is greater. Concrete with a maximum size aggregate of $2\frac{1}{4}$ in. is, in general, less permeable than a 1-in. maximum and 1-in. maximum less than $\frac{1}{2}$ in." These results were obtained from a large number of experiments.

IV.

THE MIXING AND MAKING OF CONCRETE.

No matter what the purpose may be for which concrete is to be used, its full value can only be obtained and sound work secured when the following conditions are adhered to:—

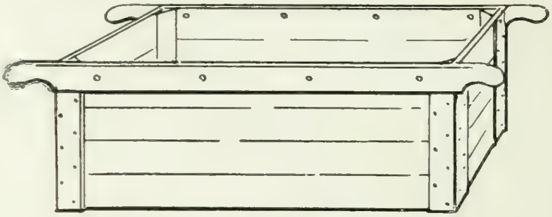


FIG. 1. CONCRETE MEASURE.

1. The aggregate should be graded with as much care as possible and washed clean.

2. The aggregate and matrice should be accurately proportioned and thoroughly mixed.

3. Clean water, quite free from any impurities, should be used for mixing.

4. The concrete should be deposited in place before initial set commences, approximately not exceeding half an hour in summer and one hour in winter.

A mixing board about 10 ft. square is necessary for mixing three-quarters to a cubic yard of aggregate at a time. It should have light ledges on the under side at each end.

It should be laid to a fall of about 1 in. to 2 in., with a sump hole or catch-trough at the low end to enable the water in washing to carry thereto the dust and fine grit without taking with it the coarse sandy element. The mixing board may be in two halves, to facilitate removal.

The bottomless measure (*Fig.* 1), having been placed at the upper end of the board, is filled with the aggregate. A man at each corner lifts it off, and two—one at each side of the heap (*Fig.* 1)—turn over the aggregate with their shovels, while a third man rakes it about with a two-pronged fork similar to that used for intermixing hair in making plastering mortar, while the fourth, standing at the back of the heap, adds water from a coarse rose water-pot. The shovellers should turn over the contents of their shovels with a wrist turn, not dump it down in the same position as lifted. If once washed is insufficient, it should be repeated and the measure then placed at the upper end of the mixing board and refilled with the washed aggregate. The cement is then placed on the aggregate, the measure lifted off by a man at each corner, and the materials mixed as previously described, but dry, followed by mixing twice wet in the same way as for washing. The amount of water necessary depends upon whether the aggregate is dry or wet, absorbent or non-absorbent. In a general way it is better to use somewhat too much water than too little, to enable the particles to more readily slide into position when being deposited in place, as cement is somewhat slow in its movements; in this respect opposite to lime. Its condition should be what is generally called sloppy—*i.e.*, sufficient water should be employed to cause the aggregate to slide into place readily, but insufficient to carry away the cement. Cement has a peculiarity in parting with the excess of water unnecessary for mixing with sand to form mortar; this may be proved by placing some sloppy concrete in a small open box with a number of small holes in the bottom and through which colourless water will pass. Similarly water will drip through the joints of the boards of the temporary platform on which concrete is being deposited for a suspended floor, and which possesses an alkaline taste.

No. 58 Technologic Paper of the American Bureau of Standards contains the following :—"The most satisfactory consistency, as the results of the tests (about 20,000), from the standpoints of strength and durability, is a quaking or mushy mixture, and the error should be on the side of allowing too little rather than too much water, providing it is properly spaded or worked into place on the joins."

Cement is sold by weight, but sacks are usually assumed to hold two bushels when filled at the works, but somewhat less on delivery owing to compression in haulage, but, if taken at two bushels, the size of the aggregate measure can be readily ascertained by multiplying the proportion of the aggregate by two. Thus a 1—8 mixture requires the measure to hold $8 \times 2 = 16$ bushels.

The process described for washing the aggregate and mixing the materials will appear apparently to incur a considerable amount of labour. Practically it is otherwise.

A hand power revolving machine for washing and mixing the materials is not so effectual, except for small quantities, and a power mixer is out of the question and is costly, except for extensive works.

V.

FOUNDATIONS.

Concrete for foundations should have either ground lias lime or cement as a matrice, the proportion of the former about 1—6 and the latter 1—10 for buildings of a moderate height. Ground hydraulic lime can be obtained at most lime works of any importance.

An economical arrangement is to adopt a raft foundation in place of the ordinary class of wall foundation.

A raft foundation consists of a layer of cement concrete 4 in. to 6 in. or more in thickness covering the entire area of the building, and on which the walls, partitions, and chimneys are built. Quarter or $\frac{3}{8}$-in. iron rods, about 6 in. apart, should be embedded in the concrete about an inch from the under side, and upon this another layer of similar rods at right angles thereto.

The ends of the rods should be bent up or down a little at the ends.

A raft of this description forms the base for the ground floor or paving, and if made of boiler ashes or other softish material ordinary floor boards can be nailed thereto, and dry rot in timbers avoided.

For a raft the proportion of materials should be 1—6 or 1—7. The concrete should be levelled straight and true, and if wood stumps are used for the purpose they should be withdrawn, otherwise they may acquire dry rot, and possibly transmit it to any adjacent woodwork. If the soil is loose, or has been dug over, the loose portion should be removed and rough core, consisting of any hard material broken to a 3-in. gauge and less, well rammed, substituted. The concrete should be deposited on a base or core of similar materials, 6 in. to 9 in. in depth, broken to pass a 2½-in. mesh, and well rammed or rolled with a heavy iron roller. Previous to nailing boards to the concrete it should be straightened with cement and ashes sand 1—4, and allowed to get quite dry, or dry rot will probably be transmitted to the boards.

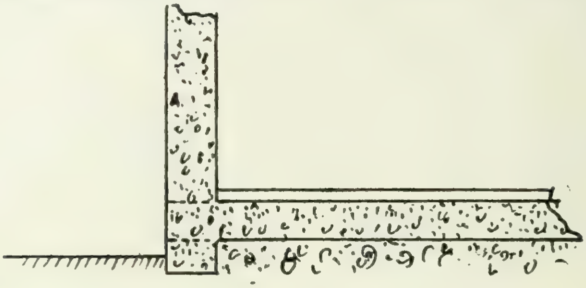


Fig. 2. Section of Wall and Raft Floor.

As the floors may require to be 9 in., more or less, above the surrounding ground, sufficient hard core or bottoming must be used to allow for this and also to excavate trenches and concrete below the external walls. (*Fig. 2.*)

Raft foundations have been used for many years past on very loose soil, and with success.

VI.

WALLS.

Concrete walls are of various descriptions, but usually limited to solid blocks, hollow blocks, slabs, and monolithic called in America "poured concrete."

SOLID BLOCKS.

Blocks can be cast in wood moulds, the bottom, called the pallet, being placed loose in the mould. The inside of the mould should be brushed over with soft soap in a semi-liquid state or with Leeds grease or a non-drying oil and paraffin mixed, to prevent adhesion of the concrete to the mould. If a fair surface is required the mould should be skimmed over, after the oil or grease has been absorbed, with cement or cement and sand mortar, 1—2. Blocks with a fair, smooth surface require the aggregate to be a finer grade than if only rough or coarse blocks are wanted, or the arrises will be rough and jagged. It is advisable to experiment with a few blocks with different grades of aggregate before fixing on the one to be used, commencing with one graded to 1-in. mesh down to coarse sand. The wood mould is liable to swell and cast from the effects of the water contained in the concrete, to avoid which it is advisable, where a large number are required, to fix sheet iron or zinc to the inside faces of the four sides. The divisions and the pallet or the entire mould may be made of cast-iron. Wood clamps or cleats are necessary to hold the parts of the mould together and prevent the concrete from forcing them apart. The necessary rebates to be left in the concrete for door and window frames must be provided for when the blocks are being made. A mason should fix the blocks. Ordinary labourers are out of the question if good work is to be obtained.

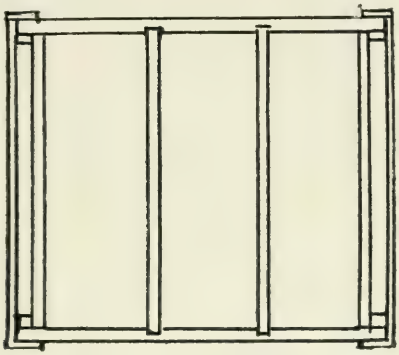


Fig. 3. Block Moulds.

Fig. 3 is a plan of a mould of this description for making three blocks at a time, but more can be made if required. The dimensions of the mould inside between the divisions would be the length and width of the block, and the depth the thickness of the block plus the thickness of the pallet. The mould (*Fig.* 3) should be soaked in water for a time, or, better still, covered with a thick layer of wet sawdust for twenty-four hours before use, to prevent warping and twisting.

If a smooth face is required the pallet should have a thin coat of cement and sand, one and one, applied, upon which the concrete is placed and well tamped or pressed as it is being deposited in place. The sides of the moulds form the edges of the blocks and do not usually require a smooth face.

When the concrete is sufficiently hard the wood mould is liberated and the blocks on the pallets are removed until such time as the latter can be taken away for re-use, and the blocks stacked to season.

The moulds should be cleaned with a brush of any particles of concrete that may have adhered thereto, before they get hard. Any imperfections in the blocks should be made good with cement. The pallets or bottoms of the moulds should fit in loose, to allow for swelling, and be reversed each time they are used.

HOLLOW BLOCKS.

Hollow blocks have been used to a considerable extent especially in America, with a view of ensuring dryness, although the object is not always attained. Moulds for hollow blocks are difficult to make with wood, are troublesome in use, and as a rule do not pay. Special machines are more satisfactory, but are costly. They compress the material more effectually than can be done by hand. Gravel is not a good aggregate for either solid or hollow blocks owing to the difficulty of cropping or cutting them to form closers or for other purposes, and in fixing door and window frames thereto. Where an inconsiderable number of hollow blocks are required, not sufficient to permit of purchasing a machine, they should be obtained from a manufacturer.

SLABS.

Slab walls usually consist of cast slabs 2 in. to 3 in. in thickness for the external and internal sides, with a 2-in. cavity to ensure dryness, and the two sides tied together with metal wall ties. They have the reputation of not always being damp-resisting otherwise. Slabs are generally made by what is known as the dry process—*i.e.*, the aggregate is of coarse sand size or somewhat larger, and only sufficient water used in the mixing to make it of a plastic condition, so that if squeezed in the hand it will retain its shape. It is called the dry process, in contradistinction to concrete made in the ordinary way and called the wet process. In a general way the latter makes the densest concrete, and is more weather-resisting. The advantage of the dry process is that castings can be quickly removed from the moulds. The concrete should be deposited in the moulds in small quantities and be well tamped. The dry process is applicable to blocks as well as slabs.

Wood moulds answer the purpose for concrete slabs, but are better faced with sheet iron or zinc, and better still if cast-iron is substituted, as the latter will last for many years. Machines made specially for the purpose are more suitable and compress the concrete more effectually, but are expensive.

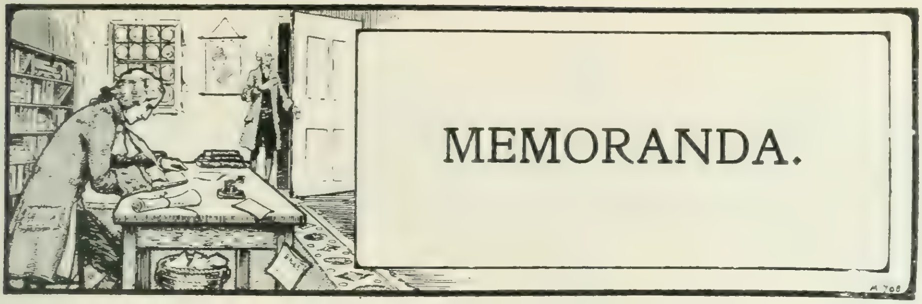
If silicate of soda in the proportion of 5 per cent. of the amount of cement used is added to the water it hastens the hardening, and immersion in a bath containing 5 or 10 per cent. of silicate effects the same object. Four per cent. of calcium chloride increases the strength and hastens the hardening. It should be dissolved in the water used for mixing the materials. The United States Bureau of Standards found that 4 per cent. of chloride increased the strength of cement 100 per cent. in twenty-four hours, and my experiments gave a similar result. Silicate of soda and calcium chloride are cheap if purchased in considerable quantities, and neither injures the concrete so far as is known.

A pallet should be used as described for blocks, and, if a smooth face is wanted, a thin coat of cement and sand mortar applied thereto, as for blocks. Imprisoned air in the soft concrete will sometimes cause pinholes on the surface of castings, and these should be stopped with neat cement. Where a large amount of cast work is done a vibrating trembler is used to expel the air, but this is not practicable on a small scale.

The proportion of materials is usually 1—3 to 1—5, but it is advisable to make two or three specimens, to ascertain the best results. The usual size is 24 in. × 9 in. When removed on the pallets the slabs should remain thereon until hard enough to be released and stacked away in the open air or in a building protected from the sun's rays.

Fig. 3 applies to slab moulds as well as block moulds.

(*To be continued.*)



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Reinforced Concrete Vessels.—The Marine Department of the Board of Trade has issued a handbill (No. 397) containing preliminary instructions to builders and owners of sea-going reinforced concrete ships, and for the guidance of the Board's surveyors.

Such vessels must comply with the requirements of the Merchant Shipping Acts.

With regard to the assignment of a loadline, in accordance with Section 438 of the Merchant Shipping Act, 1894, and Section 7 of the Merchant Shipping Act, 1906, the authority to whom application will be made for such assignment must be supplied with full information of the structural arrangements upon which the strength of the hull of a reinforced concrete ship depends, and the vessel must be built under the inspection of the surveyors of that authority, which will be either Lloyd's Register, the British Corporation, the Bureau Veritas, or the Board of Trade. The application should be accompanied by detailed calculations of the strength of the vessel, drawings showing the construction of the vessel and arrangements of reinforcements in detail, and a general specification of the materials to be used and the methods of construction to be followed.

The loadline disc of such a vessel, and the marks in connection therewith, are to be permanently marked on a steel plate 33 in. by 18 in. by ¼ in. embedded in the concrete, flush with the outside, and suitably secured.

If application for assignment of a loadline to an unclassed vessel is made to the Board of Trade, a special fee of £5 will be payable in addition to the prescribed fee for loadline survey in the case of a steel or wood vessel.

Copies of the handbill may be obtained on application to the Marine Department of the Board, 7, Whitehall Gardens, London, S.W.1.

The Concrete Institute.—An interesting paper was read last month before the Concrete Institute by Mr. Chas. F. Marsh, M.Inst.C.E., on the L.C.C. Reinforced Concrete Regulations, but we are compelled to hold over the abstract from the paper and the report of the discussion until our next issue.

The Ford Motor Works.—In our last issue we published an illustrated article on this building, but the following additional particulars may be of interest to our readers. The building was originally designed on the mushroom construction principle of reinforced concrete in order to avoid ugly ceiling beams, but the London County Council would not consider this type of design under any condition. It was, therefore, necessary to re-design the whole structure, with the result that main beams (running east and west) and subsidiary beams (running north and south) projected below the slab levels; and in order to obtain a more sightly appearance, better reflected light, and a more satisfactory sprinkler installation, a false ceiling on metal lathing at the level of the soffit of the secondary beams was introduced. This ceiling also enabled a great amount of piping to be hidden, which was an important consideration in a building where so many pipe lines for one service or another were required.

Concrete Buildings in Porto Rico.—The use of monolithic concrete for residential and office buildings is becoming more and more general in South and Central

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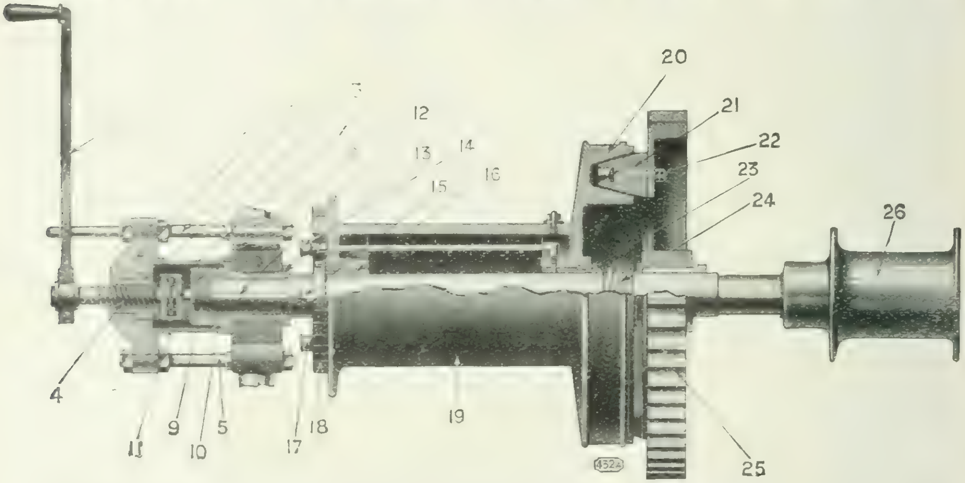

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7. Ball thrust washer.
8. Rod for moving barrel with recess for thrust washer.
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12. Barrel shaft.
13 Main bearing gun-metal.
14 and 17. Lubricators to barrel bushing.
15. Cross bar for moving barrel along barrel shaft to engage clutch.
16 and 23. Brass bushings to barrel.
18. Ratchet.
20 and 21 Clutch.

In our last advertisement we gave a general view of one of these winches. We now show a detail of the barrel. Note the ball thrust washers, brass bushings throughout, efficient lubrication, the oil bath containing the clutch gear ensuring perfect lubrication and excluding all dirt and dust. These are only a few of the distinctive features of Zenith Winches. If you are engaged on work of national importance you can have one out of stock. Call and see one under test.

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America as well as the Spanish Indies. In these countries, which are subject to violent seismic disturbances and frequent fires, the qualities of concrete for purposes of construction are especially valuable.

The first concrete building in Porto Rico, West Indies, was erected about 20 years ago, and many hundreds of such constructions have since been completed. The town, for instance, contains to-day nearly 30 concrete churches, the majority being in San Juan, the capital. Others have been, or are being, erected in Ponce and Mayaguez. Some large warehouses, costing £150,000, are about to be built entirely of monolithic concrete in the capital for the Porto Rico-American Tobacco Co. It is considered that in the next few years wood will be no longer used for houses, the designs for villas and even mansions of the new material having caught the fancy of the residents of the island to an extraordinary extent. Among other constructions now approaching completion are a range of concrete buildings for the West India Oil Co., and the Presbyterian hospital, which is to cost no more than £30,000. Within the past 20 years the population of Porto Rico has increased remarkably, the capital alone having to-day over 60,000 people, against 30,000 two decades ago.—*Times*.

Reinforced Concrete Sill Foundation for Brick Bank Protection.—The old bank protection of one of the shallow French canals comprised a 14-in. brick wall set in the 1 : 2 slope of the bank and resting on a concrete sill. This sill was held against horizontal displacement by continuous wood planks, backing in their turn against 5-in. wooden piles spaced about 3 ft. 3 in. on centre. Although a considerable length of such construction had been put in, it was found to be impracticable, because the wood soon rotted out during the periods before the canal was watered or during the time when it was not in service. The engineers therefore substituted for the combined concrete and wood sill a reinforced concrete sill. This footing structure is made up of reinforced concrete piles about 4 in. in diameter and from $2\frac{1}{2}$ ft. to $5\frac{1}{2}$ ft. long, spaced somewhat over 9 ft., c. to c., and carrying a continuous sill, which slopes on the side to the angle of the brick wall. The piles were made by boring a hole in the ground with a long-handled auger and filling this hole with concrete after the proper reinforcing rods had been placed. On top of each pile was a small rectangular head, cast at the time the pile hole was filled. After a stretch of these piles had set, the concrete sill itself was placed.

The bank protection has proved very successful and quite as cheap as the wooden ones formerly used. It is described in the May-June *Annales des Ponts et Chaussées*.

CORRESPONDENCE.

Housing after the War

To the Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

SIR,—Architects throughout Europe are concerned with the planning of cottages. It is not an easy problem, because the working man will ultimately decide whether they meet his wishes. Most of us have known expensive houses which the working man has refused to occupy, therefore the improvements and economies made must satisfy the artisan as well as the Government officials who will draw up the new bye-laws which should come into force before long.

It is said that new methods will receive the attention of the authorities, but that diffidence exists as to the adoption of any innovation unless it has been well tested.

I have been experimenting for many months with cement blocks and with various renderings on them. I have proved that a $\frac{1}{4}$-in. waterproofed cement facing to porous concrete blocks is perfectly waterproof. I have also published a brochure giving the results of my experiments and suggesting many uses of waterproofed cement for cottage building. It will probably be news to some of your readers that the British Government have erected several hundred houses with $2\frac{5}{8}$-in. coke breeze exterior curtain walls which are rendered with $\frac{3}{4}$ in. of Pudloed cement; that a flat roof can be made to span a width of 12 ft. 6 in. without the use of girders, and that bay-window roofs of concrete can be laid to a width of 3 ft. to 4 ft. without reinforcement.

At my London office, 71, Newman Street, Oxford Street, W., I have a practical demonstration of the various methods of waterproofing concrete blocks. There are shown a number of tanks made of porous coke breeze concrete blocks, some with an ordinary cement facing, and the others faced with Pudloed cement. The former tanks leak, whereas the latter are quite watertight. They can be seen during office hours by any interested person on production of their visiting card.

These and many other suggestions are gone into more fully in Circular No. 15, above referred to, and I shall be glad to send it to any person who is interested in the housing question.

Yours faithfully,

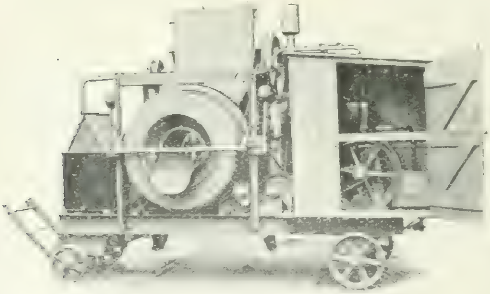
J. H. Kerner-Greenwood.

King's Lynn.

PUBLICATIONS RECEIVED.

Road Reinforcement.—The British Reinforced Concrete Engineering Co. have just published the eighth issue of this booklet, which contains interesting illustrated articles on the development of road reinforcement and "Road Maintenance in Former Times." Copies may be obtained on application to the above company at 1, Dickinson Street, Manchester.

Laxton's Price Book, 1918.—We have pleasure in drawing the attention of our readers to the new edition of the above book. Though there is no new feature added to the present edition, the List of Specialities—which was given for the first time in the 1917 edition—has been considerably enlarged and improved. Owing to the ever-increasing cost of all building materials, and the great scarcity of some, great difficulty has been experienced by the publishers in fixing prices for 1918; and prices throughout the book are based upon the prime cost prices of material and labour in November last. A short review on reinforced concrete will be found under the heading "Fireproof Construction." This useful reference book and guide is, as usual, obtainable from Messrs. Kelly's Directories, Ltd., 182, High Holborn, W.C.1. (Price 4s.)



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(*See page* 169.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIII. No. 4. LONDON, APRIL, 1918.

EDITORIAL NOTES.

REINFORCED CONCRETE REGULATIONS.

CRITICISM of regulations relating to building work is inevitable, as there are many points of view, and it is practically impossible to reconcile the interests of all the parties concerned, even when the opportunity of assisting in the framing of such regulations is given to the persons who are chiefly affected by them. This condition particularly applies in the case of reinforced concrete work, because there are still many matters which have not been thoroughly investigated and upon which no reliable data is available.

Honest criticism is, however, an excellent thing, as it is likely to provoke discussion on those items which are unduly onerous, contradictory, or partly unjustifiable, and thus the way is paved for suitable revision when an opportune moment arrives.

Some criticisms of the London County Council regulations relating to reinforced concrete were made in the paper read before the Concrete Institute by Mr. Charles F. Marsh—an abstract of this paper being given on page 207 of this issue—and while we can scarcely agree with all the views and suggestions put forward by the author, we do feel that in many respects the criticisms are worthy of serious consideration by the authorities who are responsible for the regulations. Mr. Marsh has certainly dealt with the subject thoroughly, and there are very few clauses which do not come within his recommendations for revision. In some cases he has undoubtedly made much of what are essentially minor points, but as the regulations are likely to be adopted as a basis for similar regulations in other parts of the country, it is natural that a strong effort should be made to remove any matter which is considered unsatisfactory.

Generally speaking, the drafting of a complete set of regulations for reinforced concrete work is a very difficult matter, and there is no doubt that those now in force are quite good as a whole, and it does not necessarily cast any reflection on those who are responsible for them if it is found that improvements can be made after the regulations have been in force for some time and we have had some experience in their application.

Cantilevers.

Considerable discussion appears to have taken place as to the condition which is imposed that the length of a cantilever shall not exceed five times the effective depth at the bearing, and while we do not consider that any great hardship is entailed by this regulation, there is certainly no reason why the length should not be allowed to vary with the actual maximum tensile or compressive stresses, as suggested by Mr. Marsh.

Strength of Concrete.

The equations for assessing the strengths of the various mixtures of concrete came in for some criticism by the author, and while he stated a very good case in advocating other methods, we feel that this is a matter which requires some further investigation before it can be put on a really satisfactory basis. There is ample scope in connection with this subject for some good work by the Concrete Institute, and if exhaustive experiments were made in connection with the strength of concrete of different proportions at various ages, such experiments being conducted in accordance with practical conditions, some definite recommendations could be made to the London County Council, and they could be supported by actual facts which would demand consideration. In connection with this point, we agree with Sir Henry Tanner, who suggested that a sort of Standing Committee should be established to bring up all the matters on which revision might be necessary, and if such a Committee could produce reliable results obtained by research work, it would be able to achieve its object and convince the three other Institutes who are interested as well as the County Council. Individual efforts may do good work in bringing points to the notice of engineers generally, but no results can be obtained unless the matter is dealt with collectively by the Institutes.

Steel.

Amongst other matters raised by Mr. Marsh in his criticisms was the suggestion that specification requirements for high tensile steel should be included in the regulations, and the allowable working stress for this material in tension should be 20,000 lbs. per sq. in., and this, we think, is necessary. High tensile steel has been used to a large extent all over the country, and there was no reason why it should be discouraged in London.

With regard to the value of "*m*," we strongly advocate that this be taken as constant at 15, as this is quite sufficiently accurate for all work, and calculations are simplified when the necessity of taking a varying value is removed.

The regulations specifying the distance apart of the anchors when the compressive resistance of the concrete is not taken into account certainly needs revision, as this is too stringent, and we were glad to see that this question was raised by the author of the paper.

Methods of Calculation.

Objection was raised to the methods of calculation given in various paragraphs forming part of the regulations, but we cannot see that this is at all detrimental unless it can be shown that such methods are unsatisfactory. The fact that these are given in their present form must be of assistance to those who have to administer the regulations, as they can properly insist on the calculations being in conformity with sound theory.

Design and Construction of Compression Members.

A very important section of the regulations is that dealing with the design and construction of compression members, and Mr. Marsh rightly states that these are unnecessarily restrictive.

Generally.

The statement which was put forward in the discussion that the regulations should be very stringent in order to provide a margin to cover defective work executed by speculating builders is one which cannot be justified, as it is quite absurd to penalise every competent designer and contractor because examples of scamping can be shown. If the regulations cannot be properly enforced, and unnecessary restrictions have to be put on the use of reinforced concrete, then the material should be entirely prohibited unless executed under the supervision of a reputable engineer, or additional qualified inspectors should be appointed by the County Council to assist those who have to administer the regulations. We do not wish to belittle in any way the gentlemen who are at present engaged in the duties of district surveyor, as there is no question of their competency to supervise reinforced concrete work, but it demands probably more of their time than they can properly spare without neglecting other important matters; but it is decidedly unfair if the competent designer is to suffer on this account.

There are many other points that are worthy of consideration in connection with the regulations, but the only satisfactory method of dealing with the whole question is in the hands of the Concrete Institute, who should appoint a Committee to investigate the subject in a thorough manner while remembering that it is the *letter* of the Act which must be dealt with, as the *spirit* is a thing which cannot be officially recognised, and it is therefore necessary to pay much attention to the detailed wording of any important clause.

REINFORCED CONCRETE SHIPBUILDING.

We reproduce on p. 168 an interesting telegram that we have received from the United States which marks a notable epoch in the history of concrete and reinforced concrete. The telegram tells this journal of the satisfactory launching of a reinforced concrete ship of 5,000 tons. The illustrations of this ship on the stocks were given in our previous issue, and the daily Press informs us that numerous additional ships of the same standard pattern are being laid down by our American friends.

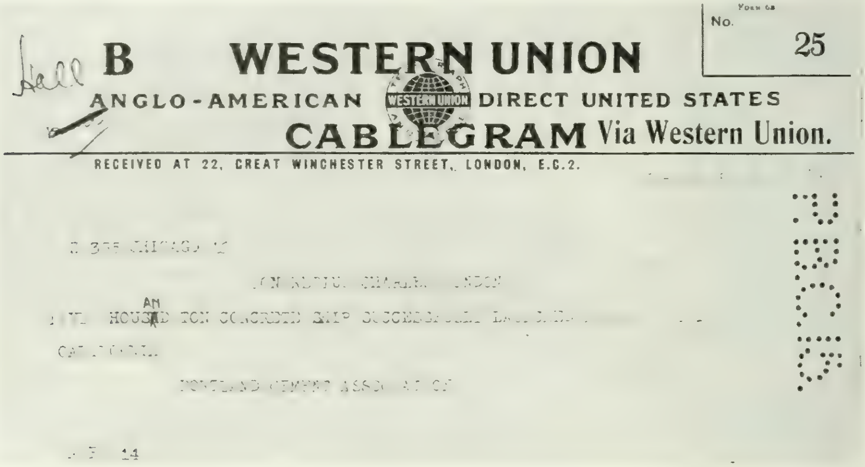
If readers will turn to one of our earliest issues of 1908 they will find an Italian sea-going barge described which we had seen in Italy. (See Vol. III., pp. 71-74, 1908.)

A development of reinforced concrete ships was to be foreseen already at that early period, but it has not been until the war, with its difficulties as to supplies of steel, that shipbuilders realised the importance and the economy of reinforced concrete for various forms of shipbuilding construction.

Our recent issues have indicated all manner and kind of ships, barges, and pontoons in different parts of the world, notably in the neutral countries of Norway and Holland. Here at home we are still limiting our efforts too much on sea-going barges, but no doubt in time our own shipbuilders will more generally realise the advantages of the larger reinforced concrete cargo boats, and our Government Departments may give that necessary encouragement and assistance that will enable ships of substantial tonnage to be constructed in what promises to become an important shipbuilding material of the future.

This journal, whilst strongly advocating the use of reinforced concrete for shipbuilding, of course fully realises both the advantages and the possible defects, and would urge the use mainly of vessels of a capacity of about 6,000 tons for cargo ships only, until three or four years' experience of wear-and-tear has been obtained and the practical effect of dead-weight and external surface are realised in the different oceans.

But for everyday general purposes of cargo and tramp steamers anything up to 6,000 tons is not only possible but advisable, and eminently economical at this present time of expensive steel and the difficulty of obtaining same. This period of dearth in steel and its high cost must obviously continue for a number of years after the conclusion of peace. It would thus be well for all concerned if Government Departments, professional institutions, and shipyards were to accelerate their endeavours in procuring reinforced concrete ships for the nation, and if we were to make the fullest possible use of the skilled advice obtainable among the engineering professions and among the contractors of this country who have had considerable experience in reinforced concrete in other directions.



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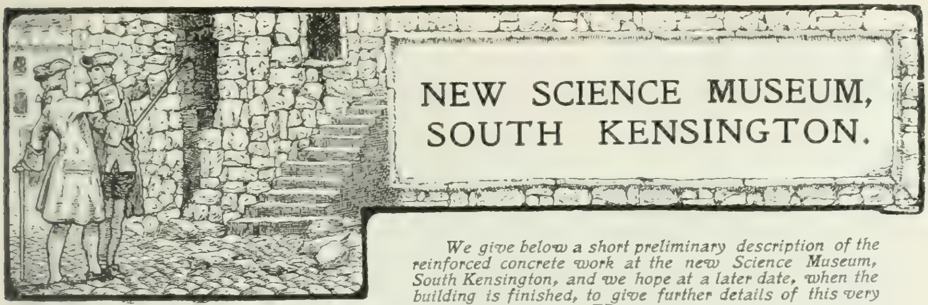
That there is a wave of interest at present is apparent to all who read the daily Press, and even at the most conservative of technical institutions papers of considerable importance are being presented on the subject, some of which we are reproducing from time to time during the current year.

Correspondence on this subject is therefore cordially invited.



NEW SCIENCE MUSEUM, SOUTH KENSINGTON.

We give below a short preliminary description of the reinforced concrete work at the new Science Museum, South Kensington, and we hope at a later date, when the building is finished, to give further details of this very important structure.—ED.

THE new Science Museum, the eastern part of which is being erected at South Kensington, and which is now nearing completion, will be one of the largest reinforced concrete buildings erected in London. It occupies the site of the old Museum, the eastern portion of which was demolished. When completed, the new Science Building will extend from Exhibition Road to Queen's Gate, between the Natural History Museum and the Imperial College of Science. The principal façade will be on Exhibition Road.

The complete building will consist of three large halls about 200 ft. by 100 ft. with roof lights. There will be surrounding galleries on the first and second floors, lighted from the sides and from central wells measuring about 126 ft. by 40 ft. and 78 ft. high. The various large halls are connected by galleries. Practically the whole of the third floor is to be one large gallery. The eastern block contains one-quarter of the three roof-lighted halls, with galleries to the north and a portion of the connecting galleries to the west. There are to be a Conference Room and Museum Offices, with an entrance from Imperial Institute Road. Museum workshops with large storage space for exhibits have been provided for in the basement.

As shown in the view of the finished elevation, from a drawing exhibited at the Royal Academy, the principal entrance to this eastern block will be from Exhibition Road. There will also be a public entrance to the Museum from the existing Metropolitan District Railway subway to South Kensington Station.

The ground floor is to be used for the larger and heavier exhibits. The central part of this hall is lighted by means of a glass roof. The various galleries on the ground floor are to be of considerable height—about 22 ft.—and on the upper floors about 20 ft. The windows lighting up the galleries are all of large dimensions and situated sufficiently high to ensure plenty of light and sufficient space for the cases containing various exhibits.

A certain number of electric lifts and staircases have been provided to give access to the various galleries.

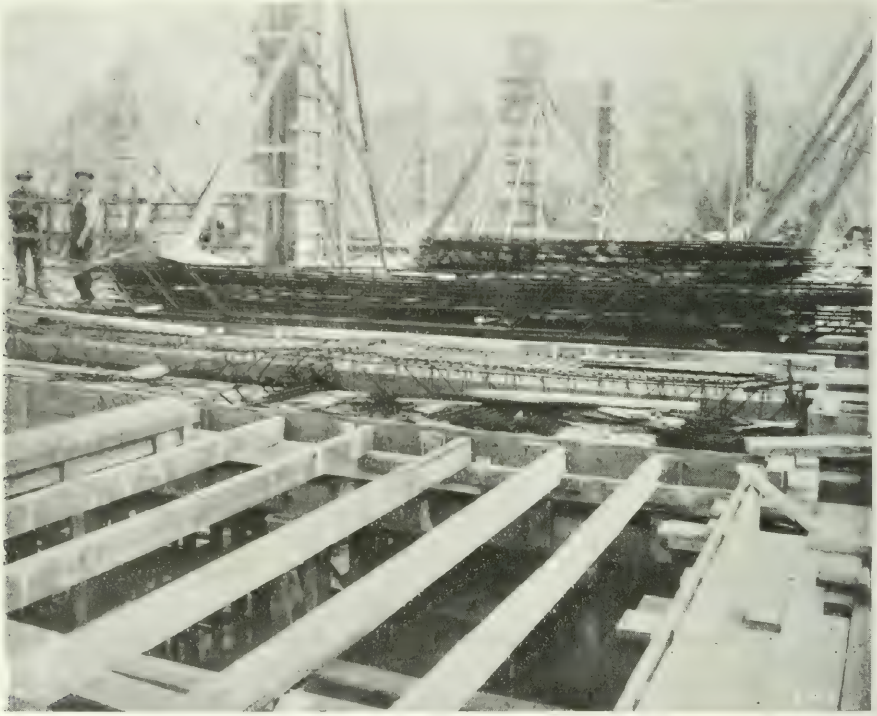
The whole of the building is to be heated by a system of hot water circulation.

The total area of flooring, when the building is completed, will be about 500,000 sq. ft.

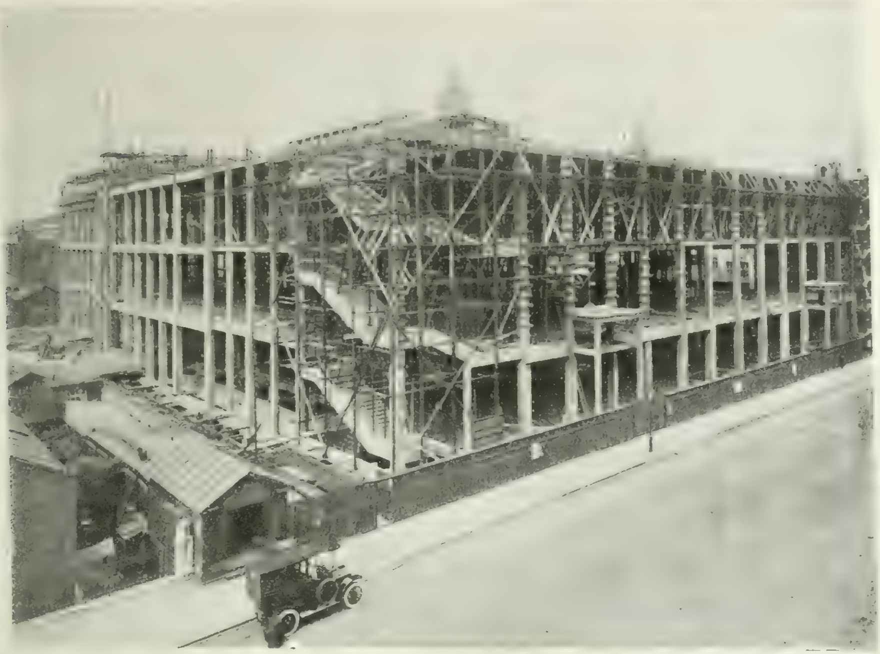
The whole of the structure, with the exception of the external walls, is constructed on the "Coignet System" of reinforced concrete, which has already been applied in the construction of the Western District Post Office and for the new Holloway Money Order Department. The external walls will be constructed in brick and stone. The principal façade in Exhibition Road and a portion of the south front are to be faced with Portland stone. The balustrades around the entrances and the lower balustrades will be made of granite. The mansard roofs are to be covered with green slates, and all the windows will have metal sashes.

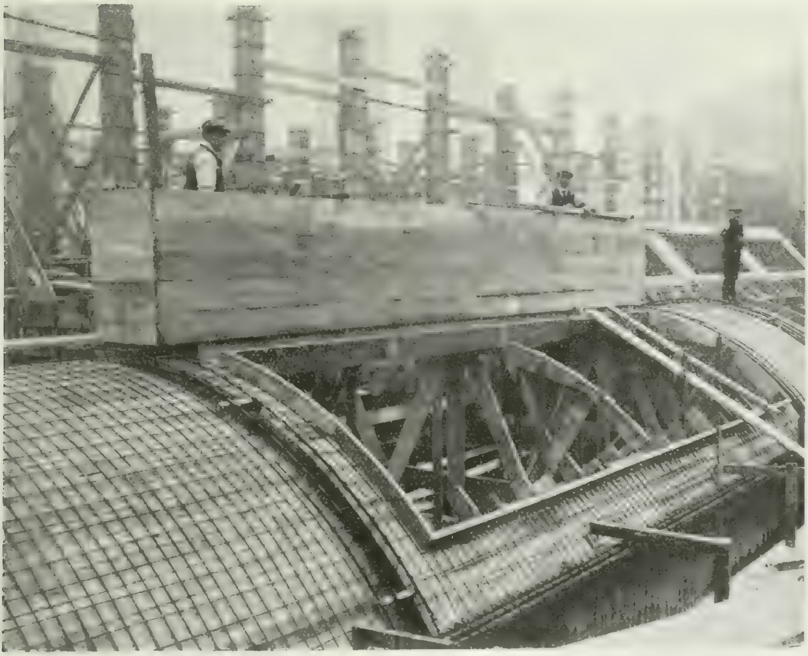
The principal features of the reinforced concrete construction are as follows :—

The whole of the bars forming the reinforcement of the pillars, beams, slabs, etc., were round bars of mild steel, varying between $\frac{3}{16}$ in. dia. and not exceeding $1\frac{1}{2}$ in. All the units forming the reinforcement of the beams were prepared in advance by wireworkers and placed in position in the moulds in such a manner that all the bars being tied together, none could get out of place during the concreting operations. In fact, in the system here employed all the bars are tied together by means of annealed wire, the principal object being to prevent the various bars from getting out of position during the concreting. The reinforcement of the various pillars was composed of a certain number of vertical bars surrounded by $\frac{3}{16}$ in. dia. ties. The slabs contain a meshwork of principal and secondary bars of small diameter. The reinforcement of the beams, however, was usually composed of units containing groups of bars—usually seven bars—having their ends bent upwards at an angle of 45° and hooked to a top straight bar, the object of this arrangement being to have the



NEW SCIENCE MUSEUM, SOUTH KENSINGTON.





New Science Museum, South Kensington

greater section of steel in the middle of the beam where the bending moment is greatest, and to utilise the ends of the bars to resist the shear as it gradually increases towards the supports, this method being therefore thoroughly economical in saving steel. In certain of the beams, however, and particularly in lintels, the units forming the reinforcement were composed by means of a top and bottom straight bar linked together by means of stirrups $\frac{3}{16}$ in. dia. and bent in the manner of hairpins with their ends hooked. All these units were prepared beforehand and tied together by annealed wire.

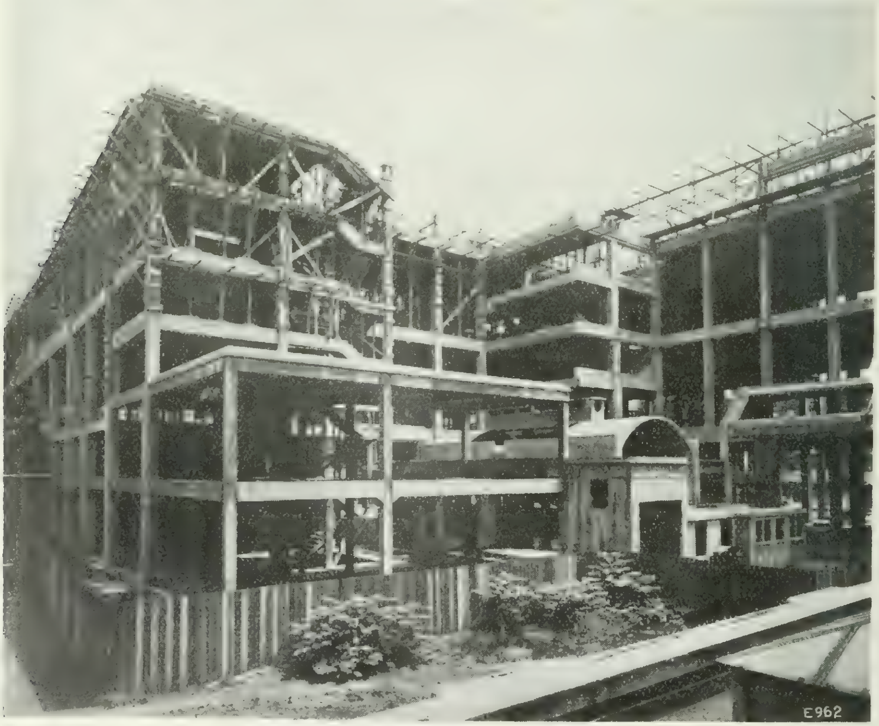
It is noticeable that this method comprises a great variety of distinctive elements. For instance, apart from ordinary flat floors and roofs, it contains arched roofs, north light roofs, and mansard roofs. There are also many staircases of different kinds, retaining walls, ducts, chimneys, etc.

A portion of the floors has been tested by means of superimposed weights being 50 per cent. in excess of the working loads, and in every case the results have been highly satisfactory.

The accompanying illustrations show the work in course of progress.

The architect of the building is Mr. R. J. Allison, A.R.I.B.A., Principal Architect, Art and Science Buildings, etc., of H.M. Office of Works.

The whole of the reinforced concrete work was designed by Messrs. Edmond Coignet, Ltd., reinforced concrete specialist engineers, of Westminster, and the work has been executed by Messrs. Leslie and Co., Ltd., contractors, of London.



New Science Museum, South Kensington.

SOME RECENT VIEWS ON SHIPBUILDING

A PRELIMINARY SURVEY OF THE POSSIBILITIES OF REINFORCED CONCRETE AS A MATERIAL FOR SHIP CONSTRUCTION.

By MAJOR MAURICE DENNY, S.B., Associate-Member.

At the annual meeting of the Institution of Naval Architects, held last month, considerable attention was this time devoted to the question of Reinforced Concrete Shipbuilding, and some most interesting papers were read on the subject. We are only able to publish part of one of these papers this month, but in our next issues we shall also publish the interesting contributions by Mr. G. Owens Thurston and by Mr. Pollock. We would here add that Major Denny's Paper was accompanied by some excellent diagrams and an Appendix explanatory of these diagrams.—ED.

General.—So long as the efficiency of a mercantile marine is judged by its dividend-earning capacity in free competition, so long will the choice of material for the construction of its units depend on economic considerations.

Up to the present for the general trader steel has proved to be the material which gives the greatest return for capital invested, and no material inferior in this respect will permanently displace steel from this position.

In the abnormal circumstances now prevailing, however, when free commercial competition is suspended, it is not necessary to examine the suitability of a material solely from the monetary point of view, and any substance which swells the volume of tonnage by drawing on fresh sources of labour and material has a chance to prove its merit on technical grounds alone. Reinforced concrete at once suggests itself as an alternative to steel, its suitability for general structural purposes being everywhere evident on land, and its application to floating structures being no longer entirely novel.

Concrete in itself is strong under compression but has little or no tensile strength ; steel is satisfactory in both respects. Concrete is durable and little affected by atmospheric influences ; steel is subject to corrosion. Concrete is obtainable in almost any locality ; steel is relatively scarce. " Reinforced " concrete combines the two materials in such a way as to exhibit the valuable qualities of each while eliminating in large measure their undesirable properties.

For all structures such as beams in which tension and compression co-exist reinforced concrete is particularly suitable, the steel taking tension and the concrete bearing compression. As almost every part of a ship's structure may be considered to be a beam under load, reinforced concrete is therefore not fundamentally unsuited to ship construction. When it is added that the use of reinforced concrete makes practically no demand on the class of labour and material used for steel shipbuilding, the justification for its trial is sufficient, and, in these times, overwhelming.

Experience has proved that steel embedded in concrete is completely protected from corrosion. It has been found that steel which was slightly corroded when bedded, after a lapse of time has shown no trace of rust, which apparently has entered into chemical combination with the surrounding concrete and formed an impervious coat. That this should be the case is fortunate, since the tensional strength of all parts of the structure of a reinforced concrete vessel is solely supplied by the steel. The principal source of deterioration in a steel ship is consequently removed, and the saving of steel shown in comparing a reinforced concrete vessel with a steel ship of the same dimensions must be partly credited to this fact. It is obvious, however, that if the envelope of concrete be ruptured in such a manner as to allow water or other corrosive substance to come in contact with the steel deterioration will at once set in, and will be the more dangerous in that its presence may not be readily detected. As will be shown when considering strength there is every reason to expect cracks in the tensional side of a reinforced concrete member, even when the steel is not stressed beyond a very moderate working load. The volume of opinion seems to be, however, that these cracks are minute and do not permit the ingress of liquid, nor impair the efficiency of the member as a whole. In this connection it should be noted that in a ship's structure the stresses are frequently alternating, often of indeterminate magnitude, and may partake of the nature of shocks. Marine conditions seem thus to be more severe than have usually to be provided for in land work. It has yet to be shown that minute cracks, which are negligible in land structures, may not in marine work develop into fissures sufficiently wide to permit the entry of water, or even, as the result of internal abrasion due to reversal of stress, form cavities sufficiently great to destroy the unity of the member as a whole.

Buildings of reinforced concrete are frequently spoken of as being fireproof, but this term is, naturally, a relative one. Considerations of weight in a reinforced concrete ship require that the " cover " shall be reduced to a minimum, and it seems doubtful whether a thickness of concrete of about half-an-inch will effectively insulate the reinforcing steel. The damage to the structure, therefore, in way of fire may be as complete as in the case of a steel ship, but it is possible that the destruction may be more localised.

The repairing of local damage in a reinforced concrete ship would seem to be a relatively simple matter. So soon as sufficient concrete and steel in way of the damage has been removed to allow of an adequate scarph between old undamaged and new reinforcement, fresh concrete can be poured into place. Since concrete " sets " under water it is not necessary to retain the vessel in dry dock during the initial stages of hardening. The actual time required for " weathering " will depend on the structural importance and extent of the damaged portion, and unless this is considerable, the vessel can return to service after a much shorter lapse of time than was necessary between launching and delivery.

Watertightness is one of the points which the naval architect will most critically examine when the question arises of replacing steel by reinforced concrete. Fortunately, experience of large tanks in land work is by no means limited, and it is possible to draw certain inferences from the behaviour of these structures. Apart from the water-resisting ability of simple concrete there are various methods of treating the material which fall generally into two categories :—

(1) The addition to the concrete during mixing of a waterproofing compound.

(2) The treatment of the finished surface with a suitable non-porous material.

The first of these is generally believed to reduce the strength, and in the present position of the industry the naval architect will be chary of adopting it. The second comprises : the treatment of the surface with cement mortar well rubbed into the pores, coating with a special mixture, and painting as in a steel ship. Even when none of these special precautions is taken, experience in large tanks shows that though leakage occurs when the concrete is first subjected to water pressure, it gradually diminishes in quantity and finally ceases altogether. This phenomenon may be explained by the deposition of salts in the pores of the material due to the action of the water on the concrete, though the exact chemical reactions seem to be of considerable complexity.

It is interesting to note that, even in this early stage of development, reinforced concrete vessels are being built to carry fuel oil in bulk, experience with land storage tanks and experiments recently made indicating that mineral oil has little or no destructive effect on the material.

Concrete is much more susceptible to abrasion than steel. The small component particles are rather readily detached from the mass and adequate shielding must therefore be arranged in way of the chafe of cables, cargo, steering chains, etc. If this precaution be neglected the steel reinforcement may be laid bare with the consequent danger of corrosion.

The ability of reinforced concrete to stand vibration, whether from propelling or deck machinery, may be called in question. The experience afforded by railway bridges and factory floors shows that little trouble need be feared from this cause, provided that the concrete is not allowed to fail progressively by unsuitable distribution of attachments.

At certain seasons of the year the construction of reinforced concrete vessels may be adversely affected by climatic conditions, a consideration entirely absent from steel shipbuilding, except in so far as the human element is concerned. In frosty weather concreting must not proceed at all, and too rapid drying must be guarded against in the presence of strong sunshine or high wnds. After the vessel has been constructed, however, it does not appear that atmospheric influences have any considerable effect ; piles in salt water exposed to very severe conditions in the form of alternate wetting and drying at all seasons of the year showing no signs of deterioration.

Constructional.—Concrete when being worked is a plastic material ; the processes of construction partake more of the foundry than of the shipyard, and the moulds required in a foundry equally have their place in the reinforced concrete shipyard. Except in one particular method which will be noted later, the whole of the outer and inner surfaces are bounded by a suitable material, the concrete being " cast " into the space between. It is at once evident that the quantity of material required for the moulds is great, and the labour required for their erection will bear a considerable proportion to the total labour required for the ship. It is therefore an obvious economy to arrange that several vessels shall be cast from the same moulds. This has a marked effect on standardisation of type. Where wood is used for the moulds it will probably be found that from five to eight vessels can be built from one lot of shuttering, though considerable repairs and renewals to the woodwork will only be avoided by skilful design and care in erection and dismantling. If the constructor were certain that a large number of exactly similar vessels were to be built he would probably decide to use for the shutters some more durable material than wood.

It seems evident that if the usual ship form be adopted, in which there is a curvature in two directions, the amount of work entailed in shaping the shuttering will be at its maximum. The minimum amount of shaping will be given by a rectangular box ; but as such a form is usually inadmissible a compromise must be effected. The best results from the point of view both of the naval architect and the reinforced concrete engineer must be sought among the class of " straight frame " forms, which yields at once reasonable figures for resistance in association with curvature in one direction only. Two suggested compromises are shown in *Figs.* 1 and 2 (*Plate I.*). the " batter " in the sides in *Fig.* 1 being given in order to reduce the chances of possible damage at the sharp bilge when lying alongside quay walls, and in the case of *Fig.* 2 to secure " flare " at the bows.

In order that the shuttering may be used several times, it must be so arranged that dismantling does not involve the destruction of the integral parts, and it must be so treated on its inner surfaces that the concrete does not adhere to it. It must be noted that both the interior and exterior walls, or shutters, are not completed before " pouring " commences. It is readily understood that the relatively small space between the walls or shutters, threaded as it is by a network of reinforcement, offers such resistance to the passage of the concrete as to render abortive all attempts to pour through long distances. Only one wall, therefore, is completed, and the other rises in stages as the concreting proceeds.

The more fluid the mixture the easier it is to work at this stage ; but an excess of moisture brings in its train undesirable qualities in the finished article. On the other hand, it is difficult to ensure that a very dry mixture shall fill all the cavities, and the "setting" is apt to be too rapid. A judicious compromise between these two extremes gives scope for the exercise of care and skill on the part of the workmen engaged on the construction.

Before any concrete is poured, of course, the reinforcement must be placed in position. This is one of the operations which brings into relief the much greater difficulty of marine work as compared with land construction. Even with a straight frame form, beyond the midship length the reinforcement may be required to be curved, and as the distance between the interior and exterior walls has been reduced to the minimum to save weight, the accurate placing of the steel and its retention in the correct position is at once of considerable difficulty and great importance. Similar operations in land work are effected under much less stringent conditions. This will probably lead in reinforced concrete shipyards to the development of a class of skilled artisans (with the usual concomitants) as distinct from the "floating" labour frequently employed in land work. To keep the reinforcement in position before, and during, pouring the component members are wired together so that the reinforcement as a whole assumes the character of a semi-rigid skeleton. The wiring is not taken into account in the strength calculations.

As an illustration of the effect on strength of inaccurate placing of the reinforcement it might be observed that if the rods in the section shown in Diagram C, Appendix I., were placed at 1 in. from the lower edge of the member, instead of at $\frac{9}{16}$ in. as intended, the moment of resistance to bending would be decreased by 16 per cent., and the liability of the concrete to crack when subjected to tension would be much increased.

A typical midship section and part profile are shown in *Fig.* 3 (*Plate II.*); the main reinforcing elements and their functions are indicated thereon, and the diversity in size is clearly seen.

The inspection of a reinforced concrete vessel just prior to the commencement of pouring is apt to produce in the mind of the naval architect an impression other than favourable. The unfamiliar network of rods scarcely suggests serious shipbuilding, and the idea that these should be replaced by the more usual and substantial sectional material at once presents itself. In the case of the frames, for instance, two angle bars connected by light bracing would appear to possess the same strength as the rods in combination with greater ease of erection and immobility during pouring. This system, however, would relegate the concrete to the inferior position of a mere cover for, and support to, a complete steel structure, and would be a return to a method long discarded by reinforced concrete engineers. In modern reinforced concrete work the steel rods fulfil their true function when employed as tension members only, while the concrete takes its full share of the work in compression. It would seem a fundamental error to cling to methods of construction found suitable in one material when dealing with another material of a totally different character. Nevertheless, it is not suggested that a measure of departure from the pure rod or mesh method of reinforcement may not be found advantageous in shipbuilding if thereby construction be simplified, even at the expense of a small additional amount of steel.

The majority of present-day reinforced concrete designs are based on the production of a vessel which should be cast in one operation, the "monolithic" method, and the foregoing remarks on construction have primarily reference to a monolithic ship. The alternative method is to cast the integral parts separately and assemble them at the slip—the "sectional" method. A few words descriptive of each will be sufficient to outline their characteristics.

In the monolithic method, in order that there should be no natural cleavage lines between adjacent areas of concrete in the completed vessel, the pouring would have to proceed continuously and fairly rapidly from the commencement. The large number of hands necessary to make the pouring a continuous operation, and in addition to effect the concurrent erection of the shuttering, renders impossible the production of a truly monolithic structure in all but very small ships. In practice, large areas are allowed to "set" before the pouring of the adjacent material is commenced, precautions being taken to ensure that the junction of the old and the new material is efficient by the employment of a pure cement "grout" as an adhesive layer. The lines of cleavage are not discernible in the finished product, but precautions are taken to "stagger" the junctions after the manner of butts in shell and deck plating of a steel ship. Notwithstanding the possibility of making joints, it is undesirable to have marked discontinuity of pouring, and the efficiency of the structure when completed is dependent on atmospheric influences and satisfactory labour conditions during construction in a manner unknown in steel ships.

When attempting to produce a monolithic structure as an alternative to simple pouring it may be noted that it is possible to apply the concrete by means of a spray, somewhat after the fashion of a sand-blast. A vessel has been built abroad by this process, and experiments are now proceeding in this country. Whether this method will prove more satisfactory than the other will be shown only by the results of practice.

In the "sectional" method portions of the structure more or less extensive are cast from moulds which should be capable of being used a large number of times. A vessel whose sides have irregular curvature, or one in which there is no great extent of parallel middle body, is evidently ill-suited to this form of construction. The sections are assembled in place, and in addition to the "grouting" referred to above, steps must be taken to provide for continuity of the local reinforcing material. As it is impossible to allow the general longitudinal reinforcement to be broken abruptly, it is obvious that it cannot form part of the sections, and must therefore be placed in position separately from them. As an example, the shell with its frames between the points A and B, and the bottom with the floors between the points C and D (see *Fig.* 3, *Plate II.*), might be cast in sections, which, in the fore and aft direction, may be either one or many frame spaces in length. After the sections are assembled the longitudinal reinforcement at gunwale, bilge, etc., would be placed and the concrete poured round it. The advocates of the sectional system state that watertightness is not difficult of attainment, and that cracks due to the contraction of the concrete on setting are less likely to develop than in the monolithic ship.

A complete answer to these two claims will be afforded only by the practical results of ships on service. The sectional system, however, undoubtedly dispenses with a considerable amount of shuttering, and is susceptible to standardisation of parts to a much greater degree than is the monolithic system.

The launching of a vessel subjects the structure to local stresses which may be of considerable magnitude. The steel vessel at the time of launching is as fit to resist these as she ever will be. The process of maturing concrete extends over a period of years and, as might be expected, the increase of strength is very rapid over the early part of that period. By constructing the vessel in such a situation that she may be waterborne without subjecting her to stresses as severe as those imposed by launching, the necessary period of delay between the completion of pouring and floating is reduced. The advantages of floating from a dock, however simple or elaborate it may be, as distinct from launching are :—

(1) The possibilities of failure of the structure during removal from the building berth are much reduced.

(2) The number of berths required to execute in a given time any programme is reduced owing to the fact that the number of ships lying "weathering" on dry land is less.

(3) The ground can be permanently levelled and prepared so as to form the exterior surface of the bottom shuttering, whereas bottom shuttering is always required (at least in a monolithic vessel) where launching is contemplated.

It should be noted that given equal speeds of construction the time from laying of keel to delivery to owners will be the same under either method, if, as is essential, the strength on the maiden voyage is to be the same in both cases.

In the future, the choice of method will be determined by the financial considerations governing the acquisition and development of the building site.

Strength.—What follows under this heading is rudimentary to the reinforced concrete designer, but is probably not quite so familiar to the naval architect, and in any case will serve to give a quantitative aspect to much of this survey.

Concrete suitable for ship construction must be of the highest quality in order to ensure watertightness and to reduce the quantity of the material used. A suitable mixture would have the following composition by volume :—

Cement.	Sand.	Coarse material.
1	1½	2½

The permissible working stresses for this mixture would be as undernoted :—

Direct compressive	730 lb. per sq. in.
Shearing	73 ,, ,,

The tensile strength of any concrete mixture is so low that all textbooks and regulations agree in placing it at zero for practical purposes.

The modulus of elasticity of concrete appears to vary with the richness of the mixture and so with the ultimate strength ; further, concrete does not follow Hooke's Law, and therefore the modulus is not even a constant quantity for any one specimen under different stresses. For mixtures usually adopted in practice the upper and lower limits may be taken as 2,000,000 lb. per sq. in. and 3,000,000 lb. per sq. in. respectively. For the mixture given above it may be taken at 2,400,000 lb. per sq. in.

The fact that reinforced concrete is not a homogeneous substance introduces methods of calculation which are not familiar to the naval architect, who is usually dealing with a material reasonably assumed homogeneous.

To produce the same elongations the unit stress in the steel must be to the unit stress in the concrete as the modulus of the steel is to the modulus of the concrete. That is to say, the stress in the steel of a non-ruptured reinforced concrete member must be roughly :—

$$\frac{30{,}000{,}000}{2{,}000{,}000 \text{ to } 3{,}000{,}000}$$

i.e., 15 to 10 times that of the adjacent concrete. From this it follows that the maximum allowable compressive stress in the steel for the mixture quoted is 12·5 times that allowed in the concrete—*i.e.*, 9,000 lb. per sq. in., and this figure must not be exceeded if the concrete, which is called upon to resist compression, is not to be stressed beyond the permissible amount. On the other hand, the allowable tensile stress in the steel cannot be fixed by any consideration of the modular ratio, since the strength of the surrounding concrete is taken to be zero. A usual figure for the permissible working tensile stress in the steel is 16,000 lb. per sq. in., which figure would correspond to a tensile stress in the concrete of about 1,300 lb. per sq. in. were such possible. As this cannot be sustained by the concrete there must be rupture of some sort, the possible results of which have been alluded to when considering corrosion.

Lacking rules for the determination of the scantlings of reinforced concrete vessels, a solution may be sought in either of two directions :—

(*a*) By the application of first principles, or

(*b*) By attempting to provide the same strength as is found in corresponding elements of a steel ship.

That the latter method will be proved in practice to be the more satisfactory is open to doubt. As is well known, a deliberate provision for corrosion is made in steel vessels, the amount of this being largely independent of size, and allotted to the different elements of the structure in varying degree. If allowance is not made for this a provision to resist corrosion in a steel vessel would appear as a provision to resist stresses in a concrete vessel in which corrosion is absent. Furthermore, for instance, the determination of the moment of inertia of a frame element, in a steel vessel, which is to be repeated in a frame element of a reinforced concrete vessel, requires the inclusion in each case of an indefinite quantity of shell plating ; and the results will vary unduly according to the choice made.

The application of first principles does not mean that every element of the structure is treated as a fundamental problem. The naval architect will naturally avail himself of the formulæ to be found in various textbooks, which, confirmed by practice, have crystallised in the form of building regulations for land work, such as those of the L.C.C. and the R.I.B.A. The basis of these formulæ is well known ; a few examples are given in Appendix I.

Consider, for instance, the shell. In a steel vessel experience dictates a minimum as necessary to provide for corrosion and to prevent undue deflection. In reinforced concrete vessels the minimum thickness is also indicated by practical considerations. It is obvious that there must be a certain "cover" round the reinforcement. Good practice seems to place this at about one-half inch. Thus the irreducible minimum thickness is about twice half an inch plus the diameter of the reinforcing element, or, say, one inch and a quarter. But such an arrangement is very uneconomical so far as strength is concerned ; the efficient use of material results in a disposition somewhat as indicated in Diagram C, Appendix I. Accordingly the thickness of the concrete must be more than twice that of the cover required if the steel is to be called upon to take any load.

If to take account of possible conditions of load, reinforcement is required in both sides, as is frequently the case, the minimum thickness becomes roughly three times the "cover" plus twice the diameter of the reinforcing element, say, not less than two inches. As a matter of fact a very usual thickness employed to-day for a vessel of 1,000 tons deadweight is about three inches. It is interesting to note that this thickness in association with a three-foot frame spacing and stringers 3 ft. apart (a not unusual arrangement) is sufficient to deal with the hydrostatic pressures set up by the maximum draught which need be considered for the ordinary type of cargo carrier. Where the shell is divided into panels by transverse and longitudinal members an interesting feature emerges. The two systems of reinforcement usually run at right angles to the bounding members, and so the relative proportions of the load carried by each system must be assessed before calculations can proceed. It can be shown that when the panel is square the proportion of the load carried in each direction is 50 per cent., and as the panel becomes oblong the proportion of the load carried by the longer system falls away until a stage is reached when it is not economical to reinforce in the longer direction. An example of the use of "reduction factors" is given in Appendix I. In passing, this consideration raises the question as to whether an intercostal in the double bottom of a steel ship is instrumental in reducing the stresses in the plating by producing a smaller panel than would otherwise exist, bearing in mind that the length of the panel so formed is usually three to four times as great as its width.

In a steel ship the effect of the weight of the material on the stress is usually neglected ; in a concrete ship this is taken into account, *vide* example (*c*) in Appendix I.

Turning next to the consideration of the hull as a girder, the bending moments are determined on the usual assumptions. It is possible to determine the moment of inertia of the midship section by a similar method to that employed for steel vessels, multiplying the area of each steel element by the appropriate modular ratio. This, however, is rather a laborious proceeding, and in practice the section is often treated as consisting of a top and bottom flange only, the effect of the vertical walls being omitted. The arm of the resisting moment is then the vertical distance between the centres of figure of the tension and compression members, the concrete being left out of account in the tension member, and the steel and concrete both included in the compression member. To emphasise the effect of modular ratio it may be pointed out that if the percentage area of steel in the compression member is three, the percentage virtual augmentation of area of concrete is three times the modular ratio, or say, 40 per cent. The bending moment to be resisted, divided by the arm of the resisting moment, gives the total load to be distributed over both flanges of the girder, which, divided by the effective area of each flange, gives the respective mean unit stress therein (see *Fig.* 3, Plate II.). The hogging bending moment is usually greater than that in the sagging condition, and so it is to be expected that the amount of reinforcing steel at the deck will be greater than that in the bottom, as shown in fact by *Fig.* 3. In order to avoid superimposing one stress upon another, those parts of the structure, whether of steel or concrete, which are already called upon to resist the principal hydrostatic or other loads are not considered as contributing to the longitudinal strength. For example, the steel rods in the deck slabs are not taken as being effective elements of the structure so far as hogging bending stresses are concerned, notwithstanding the fact that these small members can scarcely be prevented from contributing to the general structural strength. The reduction of resisting moment at the ends, consonant with the decline of bending moment, is effected simply by the gradual elimination of a certain number of the longitudinal rods.

The analysis of the effects of a shearing force show that tensile forces are set up and have to be resisted in the body of the material. This explains why the figure quoted on p. 5 as the permissible shearing stress is so low. In accordance with this fact it is found that the dimensions of a reinforced concrete member are much more dependent on shearing force than is the case in a steel member. The stresses set up by a shearing force can be resisted by rods placed in such a way as to be subjected to pure tension only, thus fulfilling their proper function. It can be shown theoretically that these rods should be placed at about 45 degrees to the top and bottom faces, and the greater the shearing force the more closely they should be arranged. An instance of this method is shown in the floors of the section in *Fig.* 3. It is not always convenient, however, to introduce such diagonal members, and tension members at right angles to the two faces are frequently substituted therefor. This disposition requires material to resist compressive stresses in a diagonal direction, which duty is legitimately performed by the concrete. Such reinforcement is fitted in frames and floors (see *Fig.* 3), and takes the form of "stirrups," or rods looped over the tension and compression members. Where not wholly required to resist shear these have the further function of preventing the reinforcement in compression shirking the load and failing through buckling. At the quarter lengths of the ship, where the shearing forces on the structure as a whole reach their maximum, additional vertical reinforcement must be provided in the shell; an alternative method is to bend up some of the main longitudinal members which are no longer required to carry tensile loads.

Weight.—The weight of a cubic foot of plain concrete is about 145 lb. The weight of a cubic foot of reinforced concrete naturally depends on the percentage of steel included therein. For land work the figure for the percentage of area of steel to area of reinforced concrete ranges from 0·5 to 1·5. Taking for the moment a percentage area of steel of 1, the weight of reinforced concrete is about 150 lb. per cu. ft., when steel is 490 lb. per cu. ft. The relative weights are therefore 1 : 3·3.

The mixture quoted on p. 5, when reinforced with 1 per cent. of steel, has a permissible compressive stress of 810 lb. per sq. in. The relative strengths are therefore 16,000 : 810, or 19·8 : 1. This elementary consideration shows that for the same conditions the relative weights are $\frac{19{\cdot}8}{3{\cdot}3}$: 1, or 6 : 1. As will be seen shortly, the area of reinforcement in a 1,000-ton vessel is more nearly 4 per cent. than 1 per cent. of the area of reinforced concrete, which reduces the ratio roughly to 4·5 : 1. Again, considering the case where 3 in. of reinforced concrete corresponds to 0·4 in. of steel (an actual case for a large barge), the relative weights are $0{\cdot}4 \times 490 : 3 \times 150$, or 2·3 : 1.

In the present early stage of development it is natural to expect that widely differing estimates of weight, both as regards concrete and reinforcement, will be advanced by various engineers for the same ship; anyone dealing with reinforced concrete vessels to-day has constant evidence of this. But it is found, as might be expected, that the percentage of reinforcement steadily increases with size of ship. Thus, average figures for percentage weight of steel to total weight of reinforced concrete are, for a 500-ton barge 11 per cent., for a 1,000-ton barge 14 per cent., for a 6,000-ton steamer 22 per cent. This last figure corresponds to a percentage area of steel to reinforced concrete of about 7 per cent., and when it is recalled that an average figure in land work is about 1 per cent., the much more onerous requirements of marine construction are again emphasised.

The shipowner is chiefly interested in the loss in deadweight-carrying ability. If a vessel of the same dimensions as the 1,000-ton concrete barge noted above had been built in steel, she would have carried somewhere between 35 and 40 per cent. more deadweight.

The quantity of steel required in this reinforced concrete vessel is less than one-third that used in the steel ship, but the finished hull weight is nearly twice that of the latter, even when allowances have been made for the omission of cement and paint in the heavier ship. Where internal volume is the measure of the carrying capacity of a vessel, this increase of weight, though not without its drawbacks, is not vital, but where deadweight is the governing factor, the advantages are heavily in favour of the steel structure.

A detailed comparison of the technical particulars of the 6,000-ton deadweight steamer mentioned above will be of interest. It is observed, however, that while the figures quoted for the steel ship are probably accurate, the weight of the reinforced concrete hull is purely estimated, respresents a much larger vessel than has yet been attempted in the new material, and lacks the confirmation of practice. With this proviso it may be added that it seems reasonable, though without erring on the heavy side.

	Steel.	Reinforced Concrete.	
Length	375 ft.	375 ft.	
Displacement	9,900 tons	9,900 tons	
Steel	1,920 tons	680	3,150 tons
Concrete	—	2,470	
Wood and outfit	400 ,,	350 tons	
Machinery	570 ,,	570 ,,	
Lightweight	2,890 ,,	4,070 ,,	
Deadweight	7,010 ,,	5,830 ,,	

From the above it will be noted that 1,180 tons of deadweight is lost, or 17 per cent. of that carried in the steel ship; that the bare hull of the concrete ship is 65 per cent. heavier than that of the steel ship, and that the lightweight of the concrete ship is 40 per cent. greater than that of the steel ship.

It is impossible to state exactly to what extent the loss in deadweight will restrict the application of reinforced concrete to the construction of cargo carriers, since the cost of construction in reinforced concrete is still somewhat conjectural.

Even though quantitative figures are thus unobtainable, it is possible to deduce certain qualitative conclusions which are of value. The following figures represent a reasonable analysis of the manner in which the total cost of the 375-ft. steamer would be made up if built in steel.

Bare hull, 53; machinery, 26; remainder, 21; total, 100. If it be allowed that the deadweight carried is a measure of the earning capacity, a reduction of 17 per cent. in this respect must be balanced by a corresponding reduction in prime cost of ship. The reduction in this instance will be 17 per cent. multiplied by 100/53, or 32 per cent. in bare hull cost, since the cost of the other two items remains unaltered. A closer investigation of the question will show that this is only a very rough approximation, and that the absolute cost of running the vessels (even if it be taken to be the same in each case), the percentage of profit assumed, and other matters of accountancy have a powerful influence on the result. These, however, all have the effect of increasing the figure of 32 per cent. noted above, and it can be stated with fair certainty that reinforced concrete will not replace steel for the ordinary cargo carrier unless the hull can be built for considerably less than half the cost of building the same hull in steel (see Appendix II.).

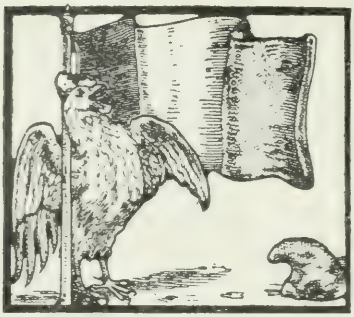
In spite of this there appears to be a class of floating structures in which reinforced concrete may well replace steel. Where the additional weight is more than counterbalanced by the durability and reduced prime cost of the new material there is reason to expect that its adoption will naturally follow.

There would therefore seem to be a future for reinforced concrete in such structures as lightships, floating docks, landing stages, hulks, depot ships, and similar craft, and it may confidently be expected that even when the artificial stimulus to reinforced concrete construction provided by present-day conditions is removed the industry will still persist on the sound footing of commercial and technical suitability.

In the preparation of this paper I wish to acknowledge the assistance of Mr. A. M. Robb, who has been closely associated with the present programme of construction from the beginning, and also the kindness of various concrete engineers who have supplied certain figures and data used in the paper.

MEMORANDUM.

An interesting paper on the subject of Concrete Shipbuilding was read last month at Newcastle by Mr. T. J. Gueritte, the publication of which we must hold over for a subsequent issue.



CONCRETE VESSELS IN FRANCE.

By the courtesy of the Editor of "Le Génie Civil" we are able to reproduce the following particulars and illustrations regarding concrete shipbuilding in France.—ED.

FOR a long time France was behind some other countries in the construction of barges and other vessels in reinforced concrete, but she has now made good her deficiencies, and is able to produce these vessels in considerable numbers.

Lorton System.—Details of a barge built under the Lorton system are shown in *Figs.* 1 and 2. The former shows on a larger scale the curved sides of the vessel, which have been designed specially to give a minimum thickness and, at the same time, to offer a greater resistance to compression and bending than can be obtained when straight sides are used. The parabolic curves shown in *Fig.* 1 have been chosen for their resistance to flexion pressure and shocks, and have permitted the thickness of the casing to be reduced by more than 30 per cent.

This barge was launched on November 5th, 1917, near the confluence of the Marne and Seine. It is 150 ft. long, 26 ft. wide over all, and 25 ft. wide and 10 ft. high internally, with a deadweight capacity of 700 tons, a draught when empty of 2 ft. and when loaded of 10 ft., and a displacement of 845 tons. When empty the vessel weighs 170 tons, of which 12 tons is the weight of the steel reinforcement. The rectangular portion of the hold is 106 ft.; the walls are 1½ in. thick and are strengthened by a webbing 1½ in. thick, which forms a series of compartments each 2 ft. 8 in. by 2 ft. 6 in. The reinforcement is arranged to form these compartments, as shown in *Fig.* 2.

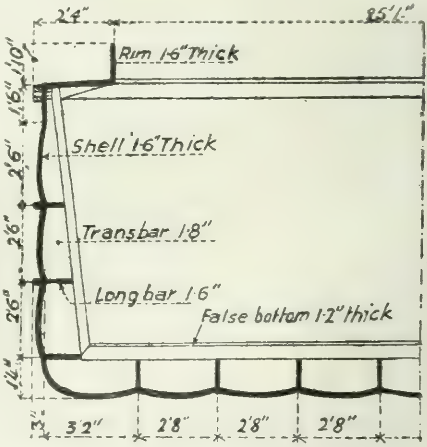


FIG. 1. HALF SECTION OF VESSEL SHOWN IN FIG. 2.

The longitudinal members are 16 in. high and 32 in. apart. The couples are 22 in. high and are spaced 40 in. apart on the base, but their vertical parts are slightly narrower. The whole system is strengthened by four closed bulkheads, one fore, one aft, and two midships, and leaving two large holds, each 56 ft. 8 in. by 22 ft. 8 in. for the cargo. The gunwales which limit the hatchways of these holds are T-beams spaced 20 ft. apart.

The ingenious use of curved pieces for the sides of the vessel enables the minimum of material to be used in its construction, and thereby ensures a lightness which is very striking in a concrete vessel. Not only is the weight of concrete required unusually small, but only 12 tons of steel are required for a boat of 700 tons capacity, as compared with 85 tons for a boat built of steel in the ordinary manner. A wooden vessel would be rather lighter, but much more costly and would require much longer to build.

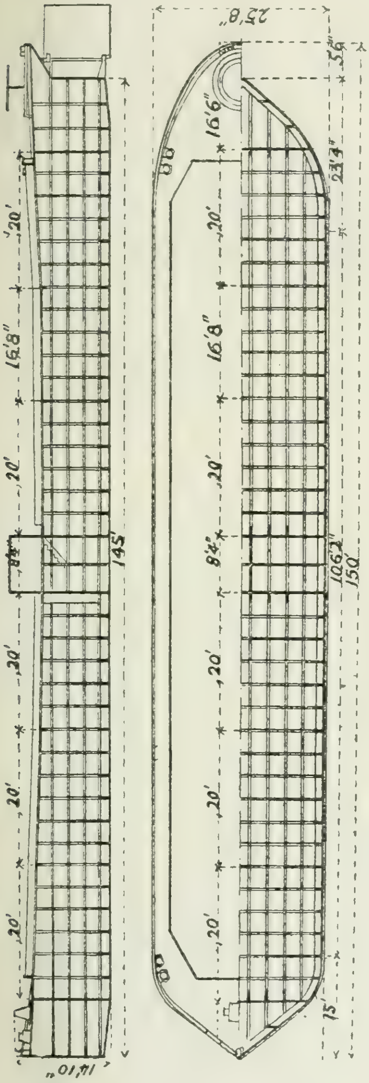


Fig. 4.—Sections and Plan of Concrete Vessel (Lorton System).

A further advantage of reinforced concrete lies in the fact that, whilst ordinary wooden and steel vessels are necessarily designed to carry a uniformly distributed load, a concrete vessel may be designed in the form of a large number of segments, each able in itself to resist the whole load if concentrated at one part, so that the vessel as a whole can be made much stronger than one built of any other material.

Concrete vessels for use on the high seas present no special difficulties. On the contrary, if the same arrangement of reinforcement is used, the greater size of the seafaring vessels will reduce the weight of material relative to capacity, and a point can be reached at which concrete vessels are no heavier than those of equal capacity, but built of wood or steel. Moreover, the construction of concrete vessels is such as to give them a much greater resistance to accidental blows, and even when they are damaged the concrete is much easier to repair than wood or steel.* (This system has been patented in France and England.)

C. A. Roux System (see *Figs.* 6-9).

The Société Entreprise Générale d'Etudes has begun the construction of a cargo boat of 450 tons capacity of the following dimensions, to be completed in April, for the transport of coal from Cardiff to Paris: Total length 152 ft., total breadth 26 ft., depth of hold 12 ft. 6 in., draught 10 ft., displacement 900 tons, weight 450 tons, deadweight capacity 450 tons, estimated speed 9 knots; motive power required: two petrol engines each of 165 h.p.

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* Mons. Lorton informs us that vessels built on this system, and now in use, exceed 5,000 tons.—Ed.

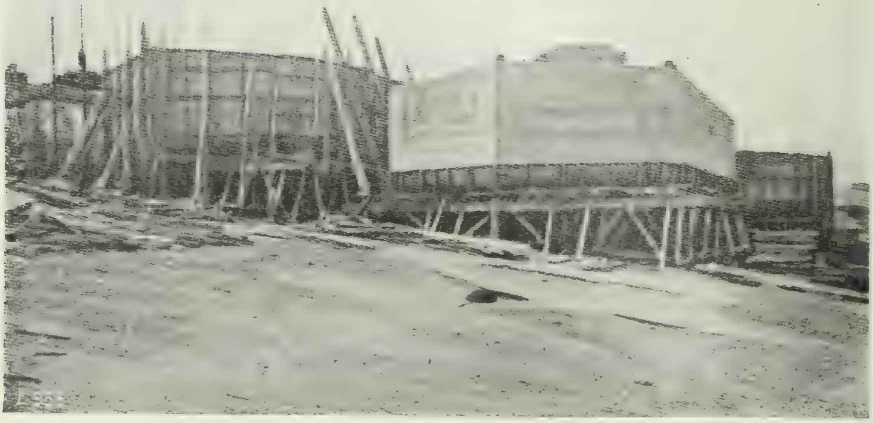


Fig. 3. Reinforced Concrete Vessel in Course of Construction.

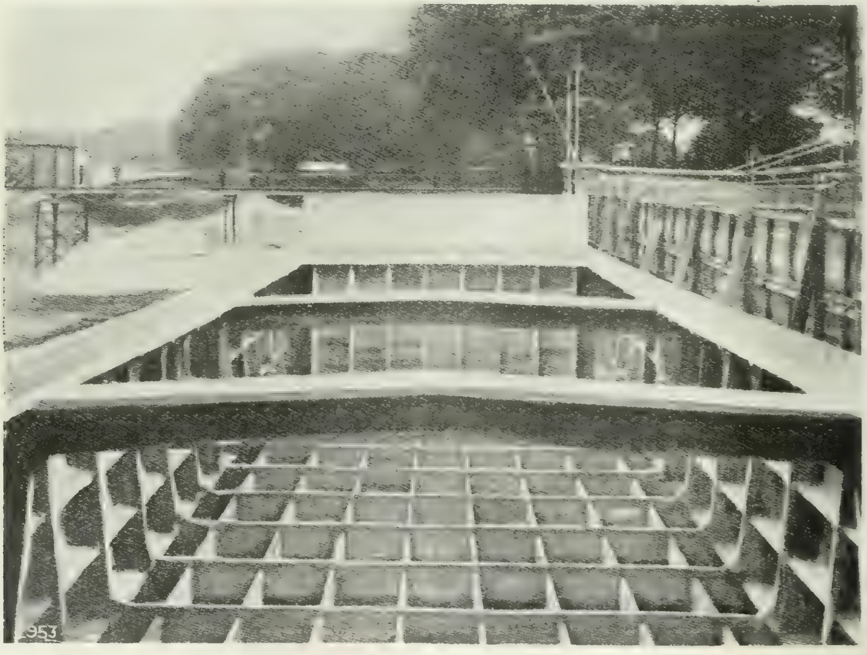
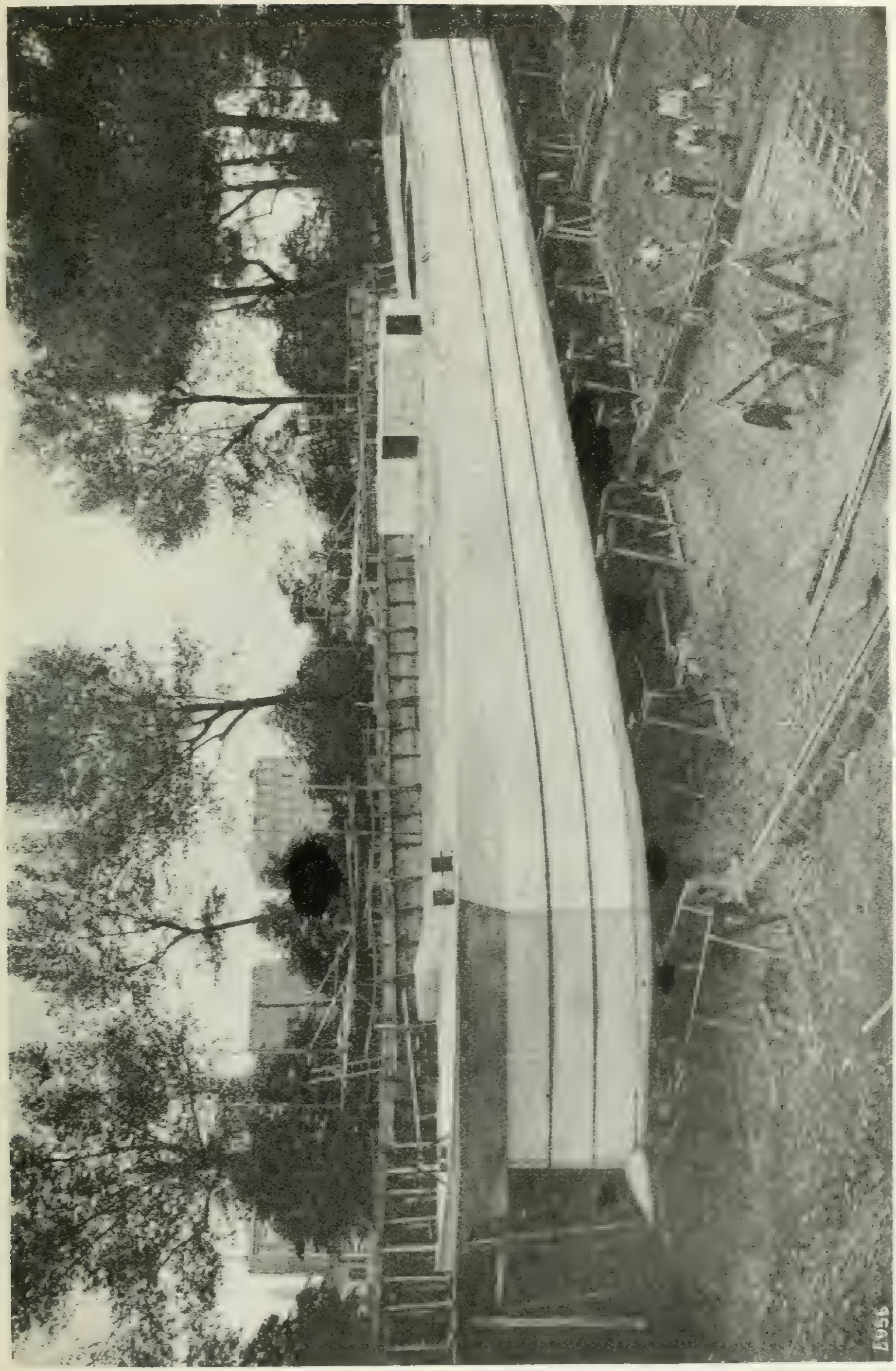


Fig. 4. Reinforced Concrete Vessel (Lorton System).



A Completed Reinforced Concrete Vessel
(Lorton System).

The shell is built wholly of reinforced concrete, 2·4 in. thick, with reinforcing bars at right angles to each other. The principal member is calculated as a beam with a high factor of safety $\left(\frac{PL}{20}\right.$ instead of $\left.\frac{PL}{30}\right)$. Quarters for the crew and live stock are arranged fore, the engines and officers' quarters being aft.

A further series of ten similar boats is to be completed before the end of the year.

The same firm has also commenced a series of boats on similar lines for the Gironde and Mediterranean; one of 1,000 tons commenced in March in the Gulf of St. Tropez, and others—of 1,500 and 2,000 tons respectively—are contemplated, the idea being to increase the capacity of each new boat by 500 tons, so as to gain experience without undue risk.

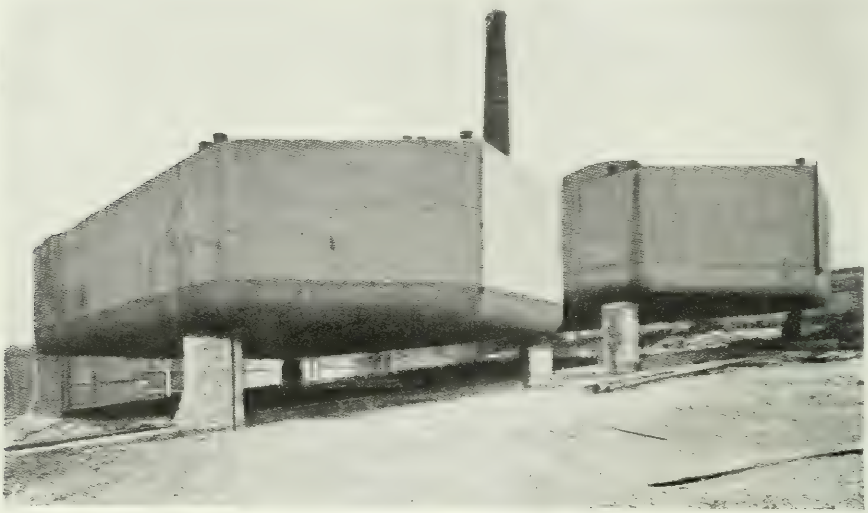


FIG. 5. VIEW OF REINFORCED CONCRETE VESSEL COMPLETED (LORTON SYSTEM).

Hennebique System (see *Figs.* 10-14).—The Association Commerciale de Constructions Maritimes has recently commenced a 1,000 tons motor boat, to be reinforced on the Hennebique system under the care of Louis Quesnel. The boat is of reinforced concrete, but the five internal partitions which divide it into six compartments are of wood, the fore and aft partitions being stayed on both sides. The first and sixth compartments are for water-ballast, the second, third, and fourth are for cargo, and the fifth for the engines.

The principal dimensions of this vessel are: Length between perpendiculars 185 ft., width 34 ft., depth of hold 19 ft., draught when empty 9 ft., when loaded 16 ft., displacement when empty 1,120 tons, when loaded 2,120 tons, engines 400 h.p., speed 8·5 knots.

The reinforcement consists of longitudinal and transverse bars, spaced respectively 4 ft. and 5 ft. apart, the lower ones being pierced with 2-ft. holes to permit the free circulation of the water to the pumps.

The concrete shearing and flooring timbers are 2 ft. 8 in. wide and 4 in. to 8 in. thick; the hull is 4 in. thick.

The hull of the vessel is of dense concrete with two coats of coal-tar, applied whilst hot. The deck is faced with about 1 in. of cork powder mixed with a magnesium oxychloride cement.

In constructing vessels on the Hennebique system it is assumed that the hull will take all inclinations up to 30° on any tack. The various elements of the loads are fixed by the assumed weights of the different accessories and the reinforcement. The *wing-transoms* and *carlings* are calculated for an internal pressure of 1,000 lb. per sq. ft. without making any allowance for their own weight or that of the cargo.

The *floor timbers* are calculated to allow for each of the following: (1) sub-

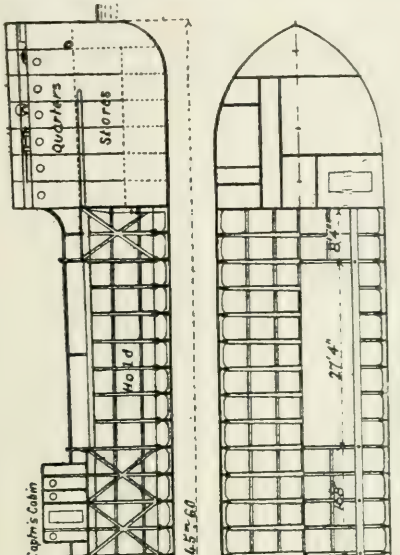


Fig. 6. Section and Plan of Concrete Cargo Boat.

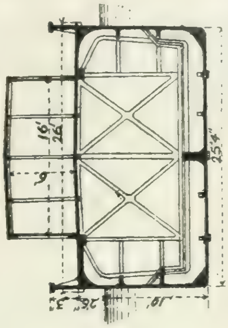


Fig. 9. Section of Fig. 6 through Captain's Cabin on Couple 18.

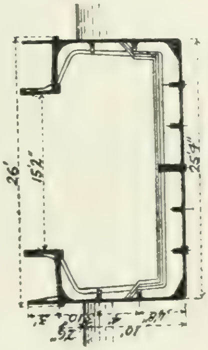


Fig. 8. Section of Fig. 6 through Hold on Couple 32.

(Roux System).

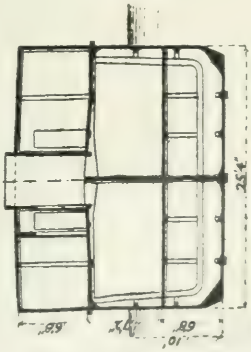
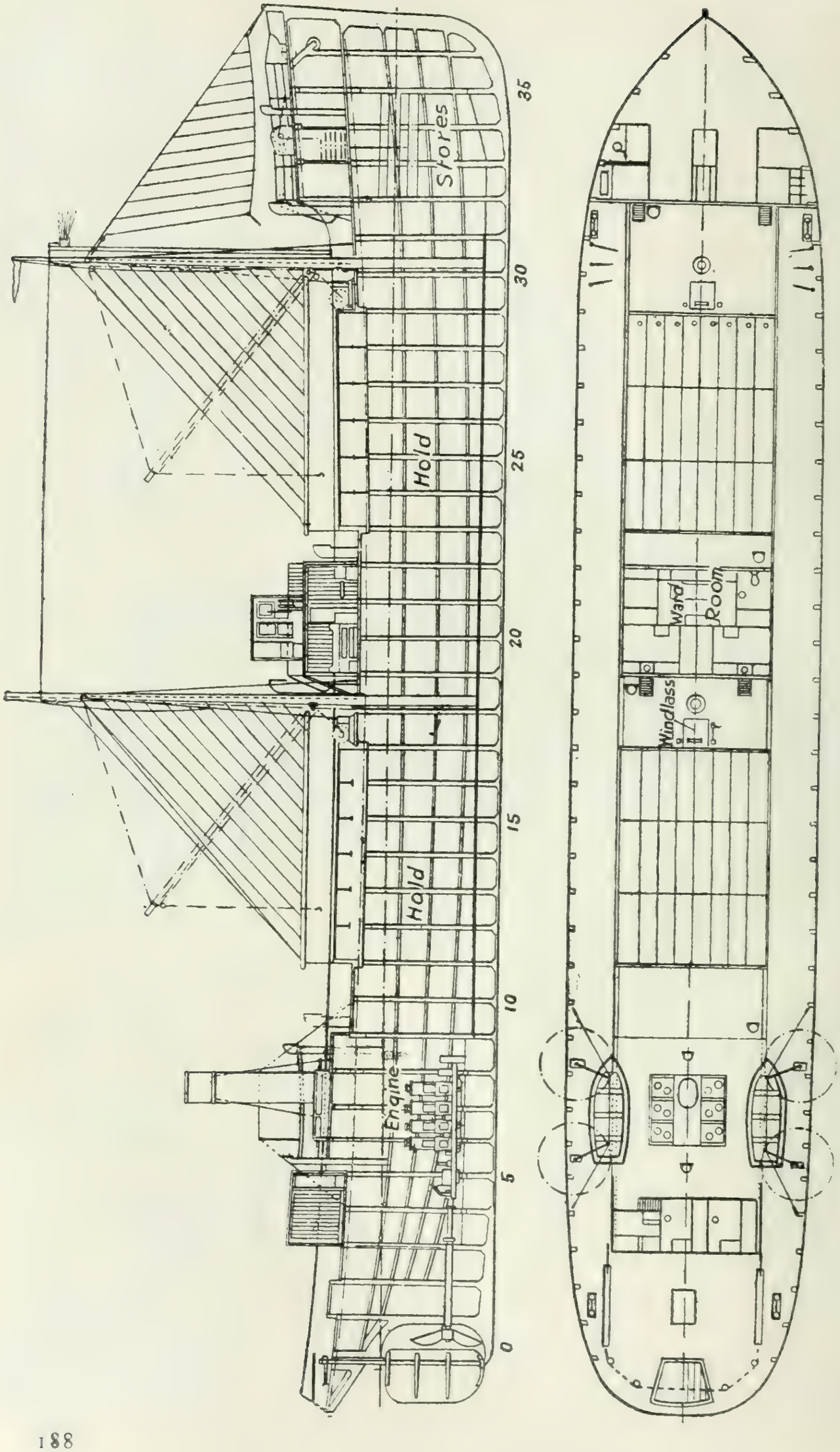


Fig. 7. Section through Engine Room on Couple 52.



Figs. 10 and 11. Section and Plan of Concrete Vessel (Hennebique System).

pressure of 1,000 lb. per sq. ft. deducted from the weight of the shell and half the load; (2) sub-pressure of 300 lb. per sq. ft. deducted from the weight of the shell plus the total load carried.

The *riders* are calculated to allow for (1) an external pressure of 1,000 lb. per sq. ft. without any internal pressure, and (2) an internal pressure of 500 lb. per sq. ft. without any external pressure. In the water-tight compartments it is assumed that the partitions are strong enough to withstand the pressure of the bulkhead when full of water.

The *upper deck* must be able to support an overload of 500 lb. per sq. ft. more than its own weight, assuming that the hatches are loaded to 1 ton and transmit this load indirectly to the supporting beams.

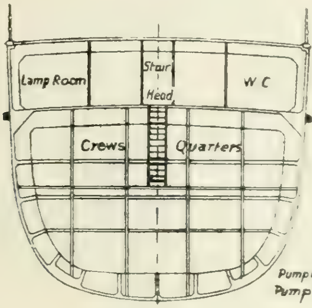


FIG. 12. SECTION OF FIG. 10 ON 6TH COUPLE.

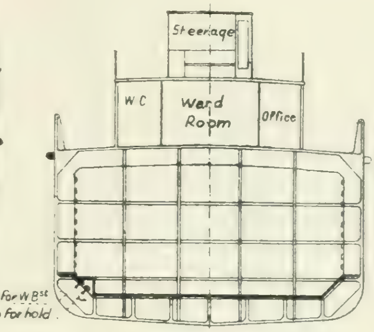
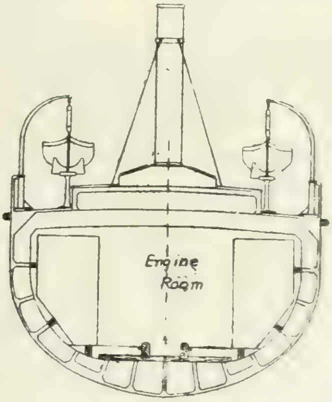


FIG. 13. SECTION OF FIG. 10 ON 21ST COUPLE.

FIG. 14.



SECTION OF FIG. 10 ON 32ND COUPLE.

It is also assumed that the hull, when lifted on the crest of a wave, is submitted to a maximum moment of flexion $\frac{PL}{30}$ (either positive or negative), in which L is the length of the vessel between perpendiculars and P the total weight of the fully loaded vessel. The section of the longitudinal reinforcement calculated to resist this stress is maintained constant on the central half of the length of the vessel, and is gradually reduced towards the ends, where it is only one-quarter of its maximum value.

The maximum shearing stress is taken as $\frac{P}{7}$ on the central three-quarters of the length of the vessel.

A longitudinal torsional couple up to $\frac{PL}{20}$ is allowed.

The reinforcement must be sufficiently strong to allow the vessel to rest on its keel or partly on its side and its keel on the beach or in a dry dock without any other support.

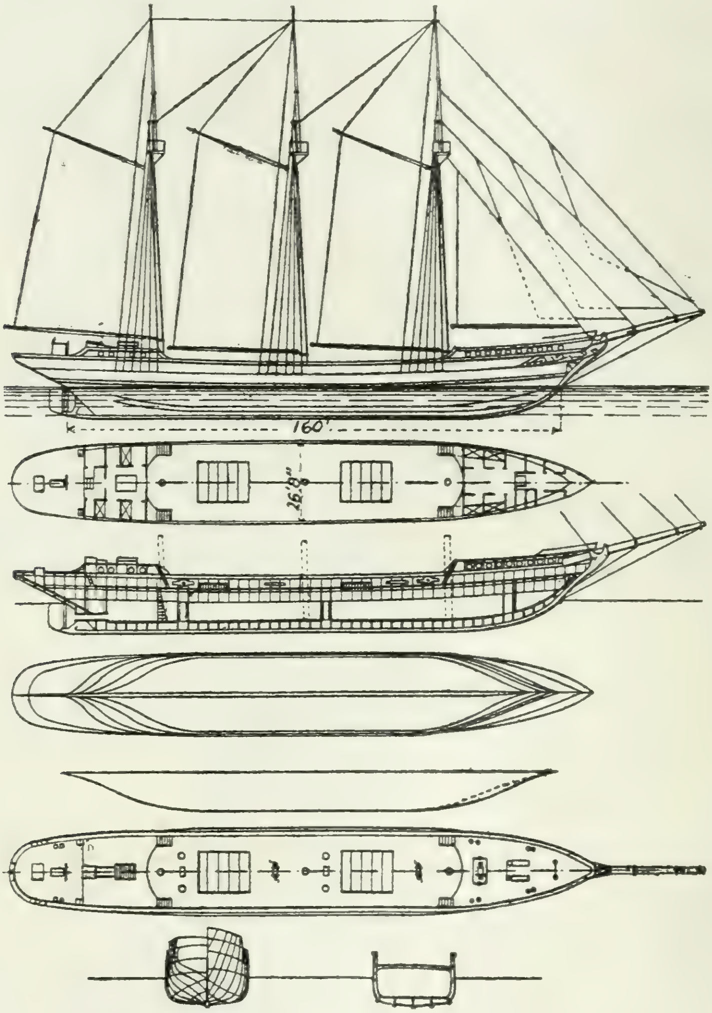


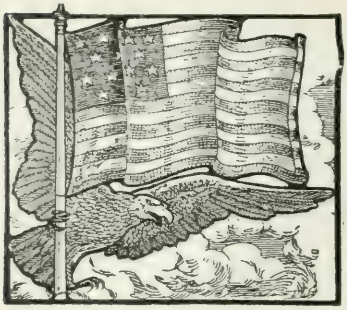
Fig. 15. Concrete Schooner (Marelle System).

Marelle System (see *Fig.* 15).—According to M. R. Marelle, a naval engineer of Marseilles, the ordinary methods of calculation and design of reinforced concrete structures are not applicable to seafaring vessels, and it is necessary to take more closely into account the enormous flexional and torsional stresses which are often applied quite suddenly and in rapid alternations to ships at sea. He declares that the strength of the concrete ought not to enter into any calculation, but that the reinforcement should be strong enough of itself to resist any force to which the vessel is likely to be exposed, this strength being secured by fixing the cross-pieces of the reinforcement firmly by screwing, soldering, or any other suitable mechanical means. He prefers to use a few reinforcing members of large diameter rather than a large number of smaller pieces. Marelle considers that the weight of the reinforcement should be one-quarter of that of a hull built completely of metal.

Fig. 6 shows a motor-driven and sailing schooner of 600 tons displacement when loaded which is capable of "doubling the Cape of Good Hope." This vessel has a double keel rising at each end to the water-line. The water-tight compartments are double. The decks are of reinforced concrete. The weight of the vessel when ready to receive its cargo is 300 tons; the free-space in the three holds is about 2,700 cu. ft.

At first sight it would appear as though this mode of construction would lose two great advantages which it is usually sought to obtain from the use of reinforced concrete—viz., rapidity and cheapness of construction. M. Marelle has stated, however, that the time required for building such a vessel as the one illustrated is less than six weeks, and undertakes to put on the stocks every three weeks a vessel of any size up to 2,000 tons, the cost of the hull not to exceed half that of a vessel of similar shape and size constructed wholly of steel.

There is a general desire on the part of French naval authorities to insist on the use of various forms of fender or sheathing to protect the hulls of concrete vessels from blows and shocks.



REPORT OF THE JOINT COMMITTEE OF THE AMERICAN CONCRETE INSTITUTE AND PORTLAND CEMENT ASSOCIATION ON CONCRETE BARGES AND SHIPS.

In view of the considerable amount of attention which is being accorded at the present time to the question of reinforced concrete for shipbuilding purposes, we think the Report recently published by the above Committee, in the United States, will probably be of interest in this country also. In the introductory part of the Report, which we publish in this issue, the various problems that arise in connection with concrete for ships are dealt with, whilst the second part of the Report, which we shall publish next month, deals with design.—ED.

INTRODUCTION.

THE idea of building ships or other floating vessels of reinforced concrete is not new. For many years and in several different countries attempts have been made from time to time to build small boats and barges of reinforced concrete. From the information at hand, apparently some of these attempts have been successful, and the vessels thus built have been in use for considerable periods. However, no definite information regarding boats built prior to the war is at hand which would assist your Committee in solving the general problem of the concrete ship.

Since the beginning of the war, however, owing to the loss of the world's tonnage due to submarine sinkings, the attention of many naval architects, concrete engineers, and others has been drawn to the question of concrete ships to replace those sunk. The scarcity of steel, wood, and labour, and the length of time necessary to construct ships of steel or wood directs attention generally to the substitution of reinforced concrete. Norway appears to have taken the lead in this work, and two different companies are already building ships of concrete. The Porsgrund Cement Works, whose vice-president and general manager, Mr. Hens Hauland, has recently been in this country, has already launched one or more ships of 100-tons cargo capacity, and is reported to have under construction a ship of 1,000-tons cargo capacity. The general design of these ships follows generally that of a framed steel ship, and your Committee has been informed by Mr. Hauland that the weight compares very favourably with that of a steel ship. No definite information is available, however, by which this statement can be verified.

The Fougner Steel Concrete Shipbuilding Company, of Christiania, Norway, has been building vessels since June, 1916. About eighteen in all have been launched up to the present time. Several others are under construction The *Namsenfjord,* about 400 tons displacement, launched some time ago, has made a round trip between Norway and England. No detailed information is available at the present time regarding these vessels that would throw light on the general problem.

On this side of the Atlantic at least two ships are under construction. At San Francisco a large ship about 5,000-tons capacity is being built, and, from information at hand, will be shortly launched. Your Committee learns that this ship is 320 ft. long, 44 ft. 6 in. beam, and 30 ft. 0 in. deep. At 24-ft. draught the displacement is said to be 8,000 tons.* The weight of the hull is said to be 2,200 tons. At Montreal, Canada, a small concrete ship which will have about 300-tons carrying capacity, has already been launched, and is now being equipped. This vessel is being constructed by the Atlas Construction Co., Ltd., of which Mr. Chas. M. Morssen is president. This ship is 126 ft. 0 in. long between perpendiculars, 22 ft. 6 in. beam, with a depth of 12 ft. 6 in. The displacement is about 650 tons. The ship will be self-propelled, and is now being equipped with boilers and engines. She will shortly make her first trip. No estimate of cost is at present available.

With the exception of the two ships noted above, little information has been gained from the ships now under construction which will assist in the solution of the concrete ship problem.

The present report will confine itself to a general statement of the several elements which make up the concrete ship problem and a discussion of the information obtained from the tentative design of a concrete ship.

In order to make any advance toward the solution of the concrete ship problem, information must be obtained concerning several points regarding which only meagre information is now available. These points taken together constitute the concrete ship problem.

(1) *The Relation between Carrying Capacity and Displacement.*—The displacement of a ship is the weight of the water she displaces, and is therefore the sum of the weight of the ship itself and its cargo capacity expressed in tons. The cargo capacity will hereafter be spoken of as the "dead weight"—following the usual practice with naval architects. Wherever displacement, dead weight, or weight of ship is spoken of it will be in terms of long tons (2,240 pounds), which is the usual practice.

It is apparent that the efficiency of a ship as a cargo carrier depends upon the relationship between dead weight and displacement. Expressed in terms of per cent. in the average cargo ship built of steel the dead weight is from 70 to 75 per cent. of the displacement, taking into account as weight of ship all spars, fittings, deck houses, anchors and chains, auxiliary engines and tanks, but not boilers, engines, or coal. In a wooden ship the dead weight is from 60 to 65 per cent. of the displacement. It is quite evident that from the difference in weight of materials it will be difficult to design a ship of concrete that will give a relationship between dead weight and displacement approaching that of steel. However, if ships are to be built of concrete for commercial use, the weight of the ship must be such as to provide a reasonable dead weight or cargo capacity for the displacement.

(2) *Transverse Strength.*—The stresses in the transverse members of a ship are, in still water, functions of the draught and the stiffness, and may be computed by mathematical processes, although the computations are long and

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* Since the above report was issued this ship has been completed and launched.

laborious. When the material is reinforced concrete the problem becomes much more complicated. Experience has shown, however, that numerous elements other than draught affect the transverse strength of a ship, such as the effect of rolling in a sea way, impact with docks or other ships, and stresses incident to going into dry dock. The transverse members of cargo ships of to-day are therefore not designed to withstand computed stresses, but are designed in accordance with various rules which embody the result of long experience in the construction and use of ships. It should be noted in this connection that granting of insurance depends on compliance with these rules.

Steel ships are of two different types : (*a*) framed ships in which transverse ribs or frames are spaced from 18 to 24 in. on centres, the plating being riveted to these ribs without intermediate longitudinal members excepting in the bottom; and (*b*) longitudinally framed ships (Isherwood) in which heavy frames are spaced from 10 to 15 ft. on centres, with intermediate longitudinals to which the plating is riveted.

From a comparison with the ordinary steel ship design it would appear to be not difficult to design transverse members of reinforced concrete of equivalent strength to steel members, the question of strength only being considered.

(3) *Longitudinal Strength.*—A ship must be able to meet conditions which are unlike any to which land structures are subject.

In determining the longitudinal strength of a ship it is customary to assume two conditions. Under the first condition the ship is assumed to be suspended between two wave crests, the length between crests being equal to the length of the ship between perpendiculars, the height of the wave being equal to one-twentieth of that length. In this case the ship as a whole is acting as a simple beam supported at the ends. This condition is termed "sagging." Under the second condition the ship is assumed to be supported amidships on one crest of the same wave. Under this condition the ship as a whole acts as a cantilever. This condition is termed "hogging." It is apparent, therefore, that when a ship is riding the waves both the deck and the bottom of the ship will be required to withstand tensile and compressive stresses alternately, the maximum tensile stress following the maximum compressive stress at very short intervals. In a steel ship the entire cross sectional area of the midship section acts to resist these stresses, taking into account, in determining the moment of inertia, all of the continuous members such as continuous scantlings and deck, side and bottom plates. In the concrete ship, equivalent strength must be provided. In the case of the concrete ship, however, only the steel reinforcement can be relied upon to take tensile stresses. The concrete, assisted by the steel, will take the compressive stresses.

The effect of the rapid change of the character of the stress in either the deck or the bottom is much more serious in the case of concrete ship than in the steel ship for the reason that owing to the low tensile stress of concrete cracks will occur at the extreme fibre under relatively low tensile stresses in the steel. These cracks, if any, alternately opening and closing, may tend to cause disintegration, with resulting leaks or impairment of the reinforcement.

At the present time little information is available as to the effect of such reversal of stress, and but little can be hoped for until an actual trial has been made of a concrete ship in a sea.

(4) *Elasticity.*—There is an almost unanimous opinion among naval architects and seafaring men generally that a concrete ship will be so inelastic that she will tear herself to pieces in a sea. While it is doubtless true that in a concrete ship there will not be the same readjustment of stresses as in a steel ship when subject to the action of a heavy sea, experience with reinforced concrete structures generally has shown that such structures have considerable elasticity, and there is ample reason for the hope that reinforced concrete will prove a suitable material for shipbuilding purposes.

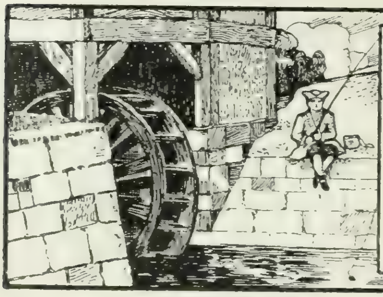
(5) *Effects of Sea Water on Concrete and Reinforcing Steel.*—Until very recently little information has been available as to the effect of sea water on concrete. The recent work of the Bureau of Standards, acting in co-operation with the Portland Cement Association, has thrown considerable light on what may be expected from the action of sea water. The result of their investigation tends to show that inferior concrete or concrete of which the surface skin has been impaired suffers serious disintegration when in contact with sea water. Inasmuch as in most instances the structures examined, which form the basis of the report of the Bureau of Standards, were built without thought as to the action of sea water (it being assumed that there would be no deleterious action), there is every reasin to hope that where the effect of sea water is appreciated, and where steps are taken in the way of selected materials and adequate workmanship, assuring a good mix and a satisfactory surface skin, the concrete will not so deteriorate.

With regard to the effect of sea water on the reinforcing steel, there is some question as to whether a thin layer of concrete can be relied upon to protect the steel from corrosion. To provide a thick protective layer of concrete outside of the reinforcing steel is practically out of the question owing to the large increase in weight. If the reinforcement, therefore, is to be maintained in perfect condition, the steel must be protected by galvanisation and by increasing the efficiency of the protective concrete by means of additional care in materials and workmanship and by a surface coating of a waterproofing character.

(6) *Relative Cost.*—Just at the present time the demand for tonnage is so great that any ship of reasonable capacity that can be used for carrying cargo will prove financially successful. The relative costs of ships of concrete and steel or concrete and wood is not therefore as important a consideration as it will be after the war, when conditions again approach the normal. However, it is necessary to have an adequate idea of the probable cost of a concrete ship as well as a comparison with the cost of steel and wooden ships.

(7) *Speed of Construction.*—Speed of construction is of vital importance in the shipbuilding programme to-day owing to the immediate requirements for tonnage. If it shall be found that the concrete ship can be constructed in much less time than a steel or wood ship, this fact will contribute largely to the success of the concrete ship.

(*To be concluded.*)

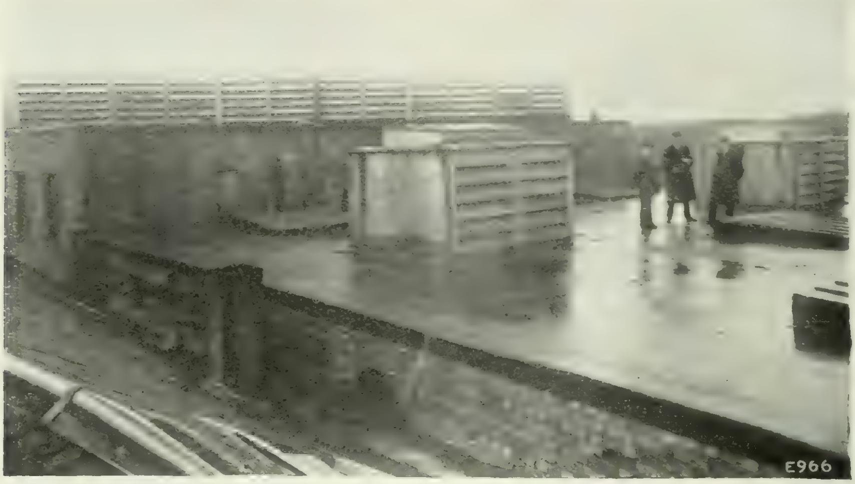


REINFORCED CONCRETE ROOFS AND VENTILATORS AT A PAPER MILL.

The following is an interesting example of the use of concrete for roofs and ventilators.—ED.

We publish herewith an illustration of an interesting example of reinforced concrete work which has just been completed at a Scottish paper mill.

The roof beams are rolled steel girders and joists spaced at 8-ft. centres. The roof consists of concrete 4 in. thick composed of four parts whinstone chips, one part sand, and one part London Portland cement reinforced with No. 8, 3-in diamond mesh expanded steel. a layer throughout near the underside, and tension strips near the topside over the intermediate bearings. The concrete is finished on the surface and breasts with mineral rock asphalt. The area of the roofing is about 600 yards.



Reinforced Concrete Roofs and Ventilators at a Paper Mill.

The most interesting features of the reinforced concrete work are the ventilators and rooflights, which are composed entirely of reinforced concrete, it being necessary to eliminate all woodwork and prevent the entry of dust.

The rooflights are glazed with cast plate glass in ferro-stone sash bars, embedded in the concrete frames of the rooflights.

The large ventilator over the grass boiling house is designed to allow for the escape of steam, arising from six grass boilers situated immediately below the ventilator. The posts, kerbs, and roofing of the ventilator were filled into the forms at one operation, the 6-in. by 4-in. and 6-in. by 6-in. posts being reinforced with steel rods which are linked to the breast rods and turned along the longitudinal beams; the roof is graded to the centre and ends and is supported on concrete ribs, the reinforcement being No. 8, 3-in. diamond mesh expanded steel. The louvres, which measure 15 in. wide by $\frac{7}{8}$ in. thick, are reinforced throughout with expanded steel and have a back throating and side shoulders to prevent dust and water from blowing back; each louvre was cast separately in a mould, seasoned, and afterwards slipped into the grooved posts, the position and correct alignment being assured by the side shoulder pieces which rest against the back of each post; the haffits were filled in afterwards, being executed in five-coat cement and sand plaster $1\frac{1}{2}$ in. thick on $1\frac{1}{2}$-in. diamond mesh expanded steel.

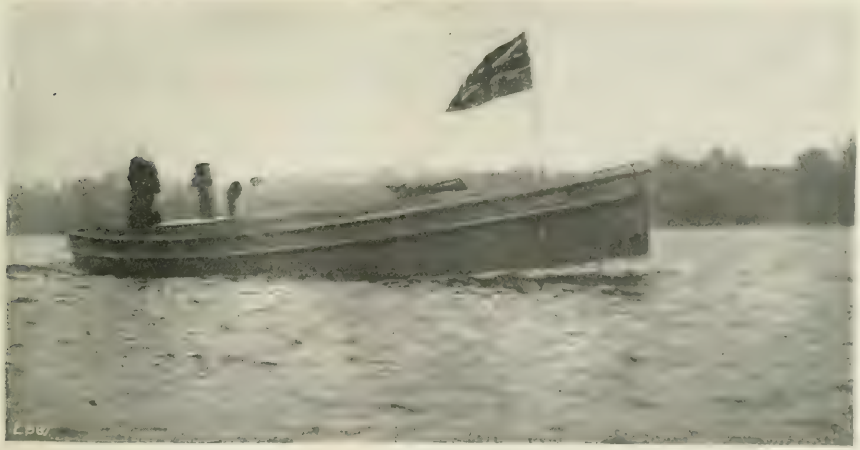
All the concrete work in the ventilators and rooflights is treated with Lillington's Metallic Liquid for its weather-resisting qualities, thus making unnecessary the use of asphalt. The large ventilator measures about 60 ft. by 9 ft. by 6 ft. high. There are also two similar ventilators, each about 9 ft. square by 6 ft. high.

Mr. J. A. McWilliam, Lic.R.I.B.A., 115, Hanover Street, Edinburgh, was the architect for the work, and the contractor for the reinforced concrete work Mr. William Robertson, 131, Morningside Drive, Edinburgh.

The expanded steel was supplied by the Expanded Metal Co., Ltd., of London and West Hartlepool.

A 20-TON REINFORCED CONCRETE CARGO BOAT.

In the accompanying illustration we show a twenty-ton concrete cargo boat launched on the Thames in the course of last month. Although we have been able to illustrate concrete barges built and used in this country, the boat here



shown is of special interest as being the first motor *cargo* boat to be launched in England. Apart from this, the method of construction adopted is noteworthy on account of its simplicity and the speed at which the ships can be turned out. By this patent system the usual timber shuttering or moulds is dispensed with; the building, in fact, is practically orthodox. The reinforcement consists of steel rods and expanded metal. Including engines and iron keel, the boat weighs about eight and a half tons. The length is 40 ft., with 8½ ft. beam and 4 ft. ¾ in. load draught. The boat is fitted with a 25 h.p. motor designed for a speed of about eight miles per hour.

This ship was built by Messrs. Holland and Hannen and Cubitts, Ltd., at Chiswick.

A number of other vessels of various types are now in course of construction and will be ready for use shortly.

MEMORANDUM.

Ministry of Munitions of War.—Order re Building Bricks.—The Minister of Munitions, in exercise of the powers conferred upon him by the Defence of the Realm Regulations and all other powers thereunto enabling him, hereby orders as follows :—

1. No person shall, as from the date hereof until further notice, sell or, except for the purpose of carrying out a contract in writing existing prior to such date for the sale of building bricks, deliver any building bricks of any description, except under and in accordance with the terms of a permit issued under the authority of the Minister of Munitions, or purchase or, except for the purpose of carrying out such a contract as aforesaid, take delivery of any such building bricks from any person other than the holder of such a permit and in accordance with the terms thereof.

2. Notwithstanding Clause 1 hereof, no such permit shall be required for the sale, purchase, or delivery of any building bricks to be used exclusively by the purchaser in the erection or carrying out of any separate and independent building or work not involving in such erection or carrying out the use of more than 20,000 bricks, or in the completion of any building or work lawfully commenced prior to the date hereof where such completion does not involve the use of more than 20,000 bricks, as aforesaid, provided always that in each of such cases the purchaser shall have given to the seller at or before the time of purchase and delivery a declaration in writing signed by the purchaser specifying the precise nature of the work for which such bricks are required and the place where the same are to be used, and that the bricks to be purchased are for the purposes mentioned in this clause and for no other purpose.

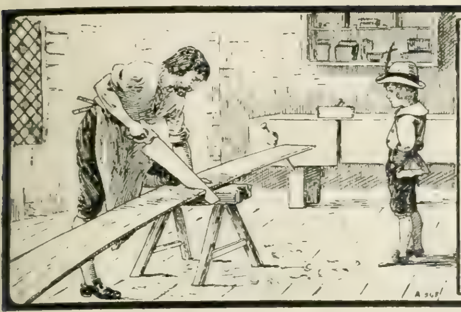
Every declaration made for the above purpose shall be true and accurate in all respects.

3. Every manufacturer of building bricks shall comply with all such directions regarding the transfer or delivery of the bricks from time to time manufactured by him as shall from time to time be given to him on behalf of the Minister of Munitions by the Controller of Building Bricks, Ministry of Munitions.

4. Every person manufacturing or having in his possession any stock of building bricks shall furnish to the said Controller such returns as the said Controller may from time to time direct concerning output, stocks, deliveries, cost of production, prices, or any other information relating to such building bricks.

5. All applications for permits under this Order shall be made to the Controller of Building Bricks, Ministry of Munitions, Whitehall Place, London, S.W.1, and marked "Building Bricks Permit," and every person selling, purchasing, delivering, or taking delivery under any such permit shall observe and perform all the conditions subject to which such permit shall be granted.

6. This Order may be cited as the "Building Bricks Control Order, 1918." (April 5th, 1918.)



CONCRETE SIMPLIFIED.

By THOMAS POTTER.

A Practical Guide to the General Use of Concrete.

(*Continued*)

The first two articles of this series appeared in our February and March issues.—ED.

VI.—(*Concluded.*)

MONOLITHIC CONCRETE.

MONOLITHIC concrete, as its name implies, is of the nature of a single stone, and is the strongest and simplest method of constructing walls. Its drawback is that wood forms or shuttering are necessary to form a trough in which to deposit the concrete, and this involves considerable expense.

In its early days patented forms were adopted, but as they were only applicable to the one building for which they were designed, without a good deal of trouble and expense for alteration, they did not obtain very general use. I designed one for my own use, in which the forms were raised as the walls progressed. The illustration, from a photograph taken of a reinforced concrete building, is interesting only as showing this in use (*Fig.* 4) forty-five years since.

The general method at the present time is to attach boards to wood posts at certain distances apart on both sides of the intended wall in any way that lends itself as the best, usually by fixing the boards flush with the inner side of the posts, and this work is of a character that any intelligent carpenter should be able to execute. *Fig.* 5 shows one of the simplest arrangements, and presents no difficulties. The posts should be not more than 9 ft. apart, and if 1-in. boards are used the latter should be connected together at intervals not more than 4 ft. apart. The boards should be of uniform thickness, or the concrete will show ridges where they join each other, and need not be planed, as cement adheres equally as much or more to planed surfaces as to sawn ones. Nor need they be dry—better otherwise—and home-grown timber, if sound, is as good for the purpose as foreign. They should be washed over each time of use with Leeds grease or soft soap applied with a brush. When removed they should be at once cleaned by scraping them with a garden hoe or a similar tool, and the loose cement brushed off with a broom before it has time to harden. The boards do not require to be ledged together.

Monolithic walls are subject to the effects of expansion and contraction—

a misfortune of all building materials owing to temperature changes—the result of which is a possibility of vertical cracks at intervals. These may be almost entirely avoided if reinforced by embedding therein $\frac{1}{4}$-in. or larger iron rods about an inch from each face—*i.e.*, two to a course—and the courses 18 in. apart in height. Over each window and door opening two extra and larger ones should be used, a foot longer than the openings and an inch or two above the soffit of the lintels, as cracks are more likely to develop at these points than elsewhere. These cracks do not go through the thickness of walls as a rule, and do not affect the strength, but are unsightly. Many walls over 100 ft. in length reinforced in this way have developed no cracks. Cast lintels are unnecessary; the concrete as deposited serves the purpose.

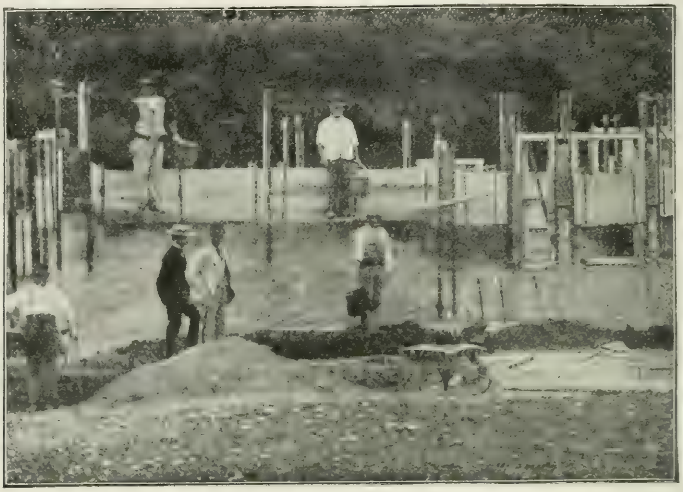


FIG. 4. PHOTOGRAPH OF A REINFORCED CONCRETE BUILDING IN COURSE OF CONSTRUCTION.

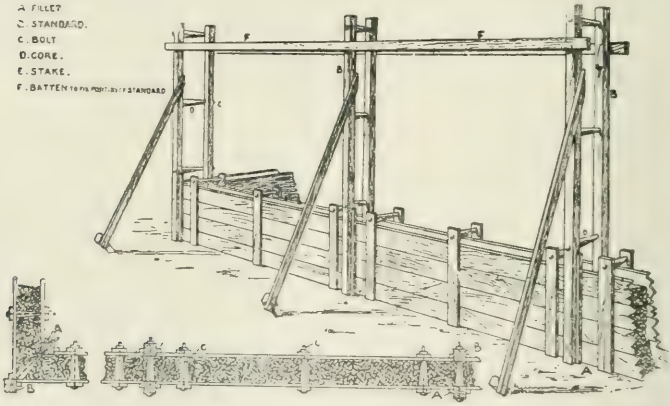


FIG. 5. SHUTTERING FOR WALLS.

Hair cracks are of a different nature. They sometimes appear on the surface of the concrete or on the cement finish coat—if any—in patches, and are scarcely visible at times. They are usually the result of the cement drying too rapidly from exposure to the sun's rays or strong winds, or possibly inferior cement. To avoid these it is as well to throw water on the walls frequently after set has taken place. All concrete is the better for being done in cold weather. The nearer the temperature to freezing-point the better; but if a severe frost is anticipated walls should be sheltered as far as practicable, or the form boards allowed to remain in position for a couple of days. After forty-eight hours frost seldom affects concrete. If, however, the concrete does not set in due course, further work should be suspended until thaw ensues, when it will probably be found that it commences to harden, the frost having only delayed the set. Where otherwise, it usually results from alternate frost and driving rain. The lesson of this is that when concrete has apparently been injured from frost it is advisable to wait a few days after a thaw, to be sure.

The boards should be changed at each lift from the trough side to the outside, that they may not warp or twist through the continuous effects of water on the one side and the sun's rays and drying winds on the other side.

It is important that all window and door frames be built in as the work proceeds. The cost is less, and they are more rigid than if fixed after, as is usually the case with brick or stone walls. The reveals are readily formed by fixing rough boards to stop the concrete on each side of the frames, with light stretchers between to keep them in place. For lintels over the frames temporary wood supports are employed, upheld by light uprights. Wall plates for fixing the ends of wood joists or similar members thereto are not required if the concrete which is to form the bearing surface is levelled straight and true.

The concrete should be deposited in place with as little delay as possible after mixing, sufficient time being allowed for the foreman to spread it evenly, and gently tamp it with a wooden stick, especial attention being given to where it abuts against the form boards. When rain is anticipated it is desirable, when work is suspended, to cover the top of the walls with boards or roofing felt. Where walls are not less than 9 in. in thickness, fragments of stone, slag, or other hard material can be embedded therein to economise the concrete. The conditions should be that they are at least 4 in. apart lengthwise of the wall, 2 in. from either face, and 6 in. apart in height. Necessarily they should be washed, shapable, the largest side forming the bed, and rubbed well in the soft concrete. In America, where this system is extensively practised, the fragments are called "plums," and are considered to strengthen the walls rather than otherwise, being of the nature of bond stones. I have never found any bad results from their use in the way indicated. If the work is being performed by contract it is not a desirable practice; but if otherwise it affords a considerable saving in materials, and is often the means of making use of a waste material. It is not always an advantage to build chimneys of cottages or other buildings with concrete; the cost of the forms and fixing and the openings for fireplaces and the flue cores is often more than if built with brick; but brick encasements built with alternate headers and stretchers, if the chimneys are of considerable size, can be used and a core of concrete filled in as the work progresses course by course.

The flues can be 9-in. unsocketed clay pipes, which are ample in size for two-storey buildings. The usual proportion of aggregate and matrice is 1—8 for walls. The wall forms should not be released under twenty-four hours. If less, there may be no apparent damage, but experience has proved that the wall may part in the centre, and so become two independent portions, and as a result its strength will be diminished.

VII.

FINISHING WALL SURFACES.

Monolithic concrete and unfaced block and slab walls do not possess an attractive appearance, and usually receive some kind of treatment as a finish, depending upon the class of building. The simplest and most economical finish, where appearance is no great object externally, is to stop with cement any defects that may be apparent on the surface, saturate the latter with water, and before it is quite absorbed wash it with cement and sand grout 1—3 of the consistency of cream. The application of water is important, otherwise the grout will dry to an impalpable powder, have no adhesive properties, and wash off with the rain.

Another process is to saturate the concrete with water and apply cement and sand mortar 1—3 as thin as possible with a plasterer's trowel. After this application the workman should take a wooden float in the right hand and a distemper brush in the left, and, having some water in a bucket in a convenient position, he should traverse the cement mortar with the float until it reaches the concrete, following up with the brush and water, to give a passable appearance. The result is that an appearance is obtained which expresses the material used in the construction—viz., monolithic concrete. This is a suitable and inexpensive method of treating the external and internal surfaces of walls of farm buildings and others of a similar character. It may be also adopted for cottage walls internally, as it renders them less liable to damage than if ordinary plaster were employed, and no skirtings are necessary. Many cottages have their walls treated externally in this way and are quite weatherproof

Cement stucco, rough cast, and pebble dash are common methods of finishing walls externally, and well known to most country bricklayers and plasterers. Cement stucco was at one time so much in common use for hiding shoddy brick walls that it still retains with many a feeling of a doubtful character. It has, however, a considerable influence in protecting walls in exposed situations if well performed.

VIII.

PARTITIONS.

Internal walls and partitions of concrete, even when thinner than the external walls, cost nearly as much if forms are used, as the same amount of labour and form wood work is necessary. For ordinary partitions cast slabs are preferable. If required to support the timbers of a wood floor over they should be 2½ in. in thickness, and if a concrete floor, 3½ in. Wood moulds answer the purpose, but these are better if lined with sheet iron or zinc, and if cast-iron moulds are adopted they last very much longer, as described in Chapter VI. The same description of moulds for wall slabs can be used for partition slabs. For bedrooms 2-in. partitions are sufficient, but where they do not come directly over a wall or partition beneath a light steel joist may be necessary to support them.

Light 2-in. partitions of considerable strength, known as granite silicon, composed of a material having plaster of Paris as a base, can be carried on any ordinary wood floor and are fire-resisting, but cost somewhat more than cement slabs. The advantages of partitions of this description are that they take up less than half the space of wood and lath and plaster partitions, are less liable to damage, fire-resisting, and vermin proof.

IX.

OVERHEAD FLOORS AND ROOFS.

FLOORS.

Overhead floors are somewhat an advanced stage of concrete construction and require considerable care. The thickness of the concrete should be determined by the distance between walls, partitions, and other supports. For an unsupported area not exceeding 150 superficial feet 4½ in. or 5 in. in thickness is sufficient, and for 100 superficial feet 4 in. This is for cottage or similar floors where the live load is a small one; if otherwise, the thickness should be increased *pro rata*. The proportion of cement to aggregate should be 1—5 or 1—6, and the latter should be graded to pass a 1-in. mesh down to coarse sand size. The reinforcement should consist of ¼-in. rods spaced 6 in. apart over the entire area of the floor and extending over half the thickness of all external walls on which the floor is supported, these rods being placed 1 in. from the underside of the concrete. Upon this reinforcement a similar layer of rods should be placed to cross at right angles, and the ends of all rods should be slightly bent upward, as this will assist in the prevention of slipping under tensile stress.

For floors to carry a heavier load ⅜-in. or larger rods should be used. The concrete should bear on the external walls half their thickness, or more if practicable. The aggregate should be by preference boiler ashes, and when the concrete has attained some hardness it should be grouted with equal parts of cement and coarse ashes sand of a less consistency than cream, well worked in with a bass broom. This prevents dirt and foreign matter finding their way between cavities in the concrete and prevents any damage that might otherwise arise from workmen's boots Each floor should be commenced and finished the same day if practicable.

Floor boards can be nailed direct to the concrete with ordinary floor brads or French wire nails, but previous thereto the concrete should be straightened with cement and sand mortar 1—5, using a long straight edge or traversing rule. This and the concrete must be thoroughly dry before nailing the boards thereto. The latter should last treble the time of boards nailed to wood joists in the ordinary way. Creosoting or tarring the underside of the boards to prevent dry rot has been found quite unnecessary; some have been removed after having been fixed over thirty years quite sound.

The platform or centering on which the concrete is deposited should be rigidly supported by upright posts and cross bearers for the boards to bear on, the former having folding wedges at bottom. If the walls are concrete the floors should finish to the outside of same, as the weight of the walls built thereon increases their strength.

The concrete should be well tamped or gently beaten with a grass beater having a piece of sheet iron screwed to the face, continuously as the concrete is being deposited in place.

ROOFS.

The construction of flat roofs is similar to that of floors, with the exception that sufficient fall must be allowed for rain to run off. The surface should be screened straight and true with cement mortar.

As roofs are more exposed to climatic changes than any other part of the building, temperature cracks are liable to occur, and for these there is no absolute remedy except by covering them with asphalt. Cement finished surfaces may not leak, but they are the exception, and cracks do not develop at times until two years or longer after they have been executed.

Cracks are difficult to deal with, as if stopped with cement or bitumen or any other material severe frosts will cause them to open again and again, and asphalting the entire area is then the only remedy.

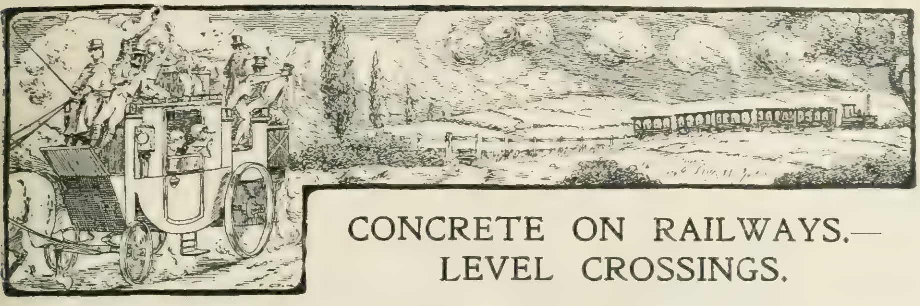
Quarter-inch or larger rods as for floors should be embedded in the concrete, and in addition similar rods or strong wire netting, $\frac{3}{4}$-in. mesh, embedded near the top to prevent contraction or assist in doing so, and if a waterproofing material is added to the cement it may afford additional help. This is assuming the roof is to have a cement finish, and not asphalted.

Concrete floors and roofs for cottages and unpretentious buildings where economy is necessary have not as yet come into general use, and they require experienced supervision, but this is not always available. The scarcity and cost of timber and other building materials for years to come may, however, lead to their more general adoption.

The forms or platform should not be struck under a week in any case, and longer is desirable. The form boards should be scraped, broomed, and cleaned without delay when struck.

The cost of flat concrete roofs if asphalted is considerably more than wood and slates or tiles, even at present prices; but if the asphalt can be dispensed with with safety, and a cement surface substituted, they would then cost less. The unfortunate feature of concrete is that its compressive resistance is so little compared with its tensile stress resistance when reinforced. The evidence generally of watertight cement roofs of a considerable size is, as a rule, based on those with an insufficient life to be accepted as safe guides, a life of two years at least being necessary before judgment can safely be passed, and even this period is not always sufficient owing to the constantly recurring stress which results in flat roofs being subject to weakening effects.

(*To be continued.*)



CONCRETE ON RAILWAYS.—LEVEL CROSSINGS.

From time to time we have published articles in our pages dealing with the many uses to which concrete can be put in connection with railway work. In the following article we publish some particulars of a somewhat novel use of concrete in this direction on the American railroads. These particulars have a special interest at the moment when the question of economy in timber is of the greatest importance. For our particulars and illustrations we are indebted to the "Railway Gazette."—ED.

THE merits of concrete as a material for level crossings, instead of timber crossing planks, have now been tested on various American railroads in the Middle West for periods of up to two years, with satisfactory results. Two somewhat different forms of construction have been used. On the Chicago, Burlington and Quincy Railroad the design is an almost exact equivalent in concrete of the usual wooden planking. Each concrete plank is $4\frac{3}{4}$ in. thick, 8 in. wide and 8 ft. long, save that every alternate end plank is 4 ft. long to permit breaking the joints. The reinforcement consists of American Steel and Wire Co. No. 27 triangular mesh and four square $\frac{1}{4}$-in. bars. As the planks are not so deep as the rail, they are supported on wooden strips, 2 in. by 6 in., laid on top of the sleepers.

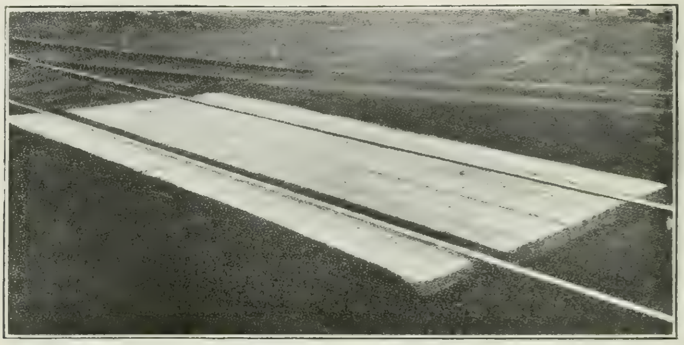
Another type of construction is that used on the Chicago, Milwaukee and St. Paul Railroad, on the Cedar Rapids and Iowa City Railroad (an electric line), and in the South Chicago yards of the Illinois Steel Co. In this form of construction the concrete slabs are considerably larger than the planks. Those between the rails of the track are of such a width that only two lines of them are required. The slabs on the Cedar Rapids line are only 8 ft. long, two being thus required for a 16-ft. crossing; while at South Chicago they are 5 ft. 6 in. in length, requiring three for a 16-ft. 6-in. crossing. At both places the thickness of the slabs is equal to the height of the rail, so that they rest directly on the sleepers without the use of filler blocks or strips. It has been the idea in all the concrete crossings to make the top surface level with the rail, except that in the case of the new design for the Universal Portland Cement Co. the slabs are crowned $\frac{1}{2}$ in. on the centre line of the track and depressed $\frac{1}{2}$ in. on the centre line between tracks.

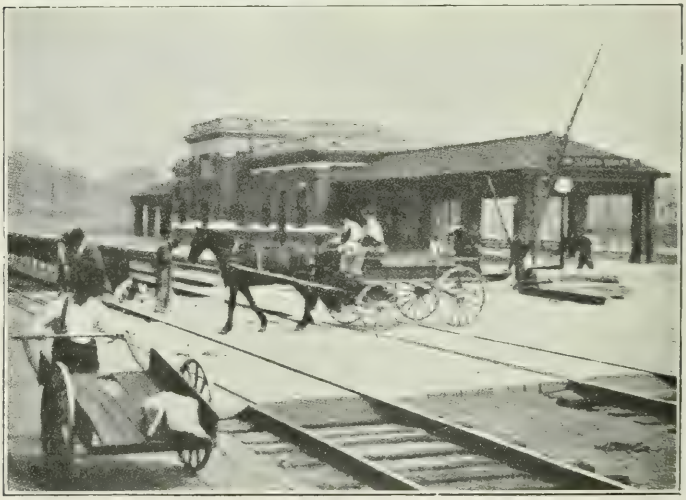
The formation of the flangeway on the gauge side of the rails is an important detail, and was provided for in nearly all the cases mentioned by some form of all-metal flangeway, such as that obtained by a rail laid on its side with the head bearing against the web of the running rail, or with the use of an angle iron, supported on a wooden strip, to give the desired elevation. With a flangeway formed in some such manner, no special detailing of the concrete slabs is necessary, although it is desirable to protect the edge of the slab adjacent to the flangeway by means of a metal guard. In the Universal Portland Cement Co.'s design a Kahn curb bar is used. A Burlington design has the slab notched out to fit under the rail and provide an adequate flangeway, without the use of an extra rail or an angle bar.

Some question has been raised as to the need of fastening the units of the concrete crossing in place, and the use of lag screws driven through holes cast in the slabs has been suggested; but in none of the installations recorded has it been considered necessary to take this precaution. In the concrete plank design used by the Burlington Railroad there has been some tendency for the row of planks next to the rail to creep, but this has been overcome by driving a stake at one or both ends of the row.

A detail that is of far greater importance is the provision of a ramp at the ends of the crossing to insure that dragging brake beams or other parts of cars will be carried safely over the top of the crossing, instead of catching in or underneath the ends. At South Chicago a ramp of this kind has been built up of wooden planks, while on the Burlington a steel plate is used for this purpose.

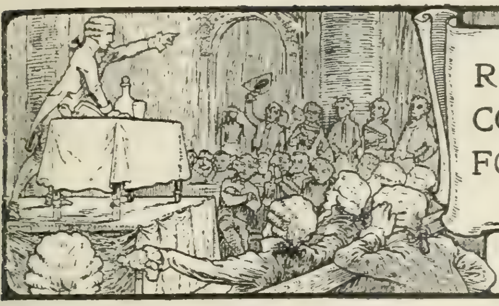
It is generally found of advantage to build units for use in installations of this kind at concrete plants where other unit construction work is carried on. The work in the field is then restricted to the preparation of the foundation and the lifting of the units into place. On the Burlington the slabs placed in the space between tracks were founded on a sand cushion tamped by means of a 25-lb. tamper and carefully levelled off. The slabs were placed ½ in. below the top of the rail, but after two or three days' service some of them worked up flush with the top. The joints between the slabs were also filled with sand. At the Illinois Steel Co.'s crossing at South Chicago granulated slag was used for the foundation bed and filling material.





[By courtesy of "The Railway Gazette."

The two crossings at Cedar Rapids have been in use for nearly two years, and a crossing on the Burlington has passed through one winter, while the other two on that line have been in service since last spring. The conclusions based on an examination of the crossings after this service indicate that the concrete crossing planks afford a serviceable permanent construction. The units are readily kept in place, and with material and workmanship suited to the purpose the concrete will stand up well under the vehicular traffic. The principal advantage of this form of construction is that it affords a roadway surface that compares favourably with that of any pavement that may be in service on either side of the tracks, while retaining the ready removal feature so necessary for the proper track maintenance.



RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

THE CONCRETE INSTITUTE.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE CONCRETE INSTITUTE.

CRITICISMS OF THE LONDON COUNTY COUNCIL REGULATIONS RELATING TO REINFORCED CONCRETE.

By CHARLES F. MARSH, M.Inst.C.E., M.C.I.

The following is an abstract from a paper read before the Concrete Institute in February, together with a report of the discussion which followed.

THE regulations relating to the use of reinforced concrete in building construction, recently issued by the London County Council, are the first of any importance in this country, and will doubtless be used as a basis for similar regulations throughout the provinces.

Regulations governing the use of reinforced concrete or any other material should be framed in such a manner as will give the greatest scope to the development of the material with all necessary safeguards, but without placing undue restrictions upon its use, such as must tend to prevent its employment in suitable cases.

It is recognised that the drafting of a complete system of regulations is an arduous and difficult matter, and that there must be a tendency for personal and collective opinions and prejudices (based on insufficient or unjustifiable premises) becoming incorporated. There must also be a temptation to err on the restrictive side and to introduce arbitrary and unwarrantable clauses.

Paragraph 2 was, it is believed, inserted to permit the construction of reinforced concrete floors, such as were permitted before the passing of the London County Council (General Powers) Act, 1909, without being subject to the special regulations. The paragraph as drafted does not, in the author's opinion, make this clear.

Paragraph 18 does not state the plane to which the angle of dispersion may extend. It is believed that it was the intention that this plane should be the axis of the main tensile reinforcing bars.

Paragraph 19 does not, in the author's opinion, give sufficient relief, and it is contended that the rate of reduction should be 10 per cent., not 5 per cent.

The limitation of the reduction to 50 per cent. is believed to be reasonable.

Paragraph 28 limits the length of a cantilever to five times the effective depth at the bearing, but it is not clear why the length should not be allowed to vary with the actual maximum tensile or compressive stresses, as is permitted in the case of a beam, under paragraph 27.

Paragraphs 42 (*a*) and (*b*), 159 and 162 will be considered together, as they refer to the strengths of the various concrete mixtures.

The proportions of the ingredients of the several mixtures given in the tables to paragraphs 42 (*a*) and 159 are unusual, and there does not appear to be any adequate reason for their use in preference to the usual method of description.

If there is any useful purpose in the new basis of proportionment, it would still be desirable that the ordinary description for the various mixtures should be also given, *i.e.*, in the table to paragraph 42 (*a*), 1 : 1⅔ : 3⅓ in the second column, 1 : 1⅓ : 2⅔ in the third column, and 1 : 1 : 2 in the last column.

There appears no sufficient justification for equations such as those laid down under paragraphs 42 (*b*) and 162 for assessing the strengths of the various mixtures of concrete, and on which the strengths of the mixtures specially referred to in paragraphs 42 (*a*) and 159 are based.

The author contends that the use of these equations does not allow sufficient strength for mixtures stronger than 1 : 2 : 4.

He also contends that the strength of a mixture does not vary directly with the ratio of the volume of sand + the volume of large aggregate to the volume of cement, and that regulations such as these should not lay down such a law without ample and sufficient justification.

Comparative tests appear to indicate that, for any constant ratio of the volume of sand to the volume of coarse aggregate, such as 1 to 2, and with a coarse aggregate of approximately the same grading of sizes and of material of approximately the same compressibility, the compressive strength of various mixtures varies directly with the ratio of the volume of cement to the volume of cement + the volume of sand in the mixture.

This result would lead to the conclusion that the compressive strength of such a concrete depended on the strength of the mixture of sand and cement, or, in other words, on the strength of the mortar of which the concrete is composed.

It is suggested that equations in the form of

$$1{,}800 r_c = c \qquad \ldots \qquad (1)$$

should be adopted under paragraph 42 (*b*), and

$$5{,}400 r_c = u_1 \qquad \ldots \qquad (2)$$

$$7{,}200 r_c = u_4 \qquad \ldots \qquad (3)$$

under paragraph 162.

r_c being the ratio of the volume of cement to the volume of cement + the volume of sand in the concrete under consideration.

With respect to the relation of u_1 to u_4, or the strength of concrete at 1 month to its strength at 4 months, so far as can be reasonably deduced from the study of various tests, there appear sufficient grounds to conclude that u_1 should be in the close neighbourhood of $\frac{3}{4} u_4$. There is no constant relationship between the values of u_1 and u_4 under the L.C.C. regulations.

The French Commission allow a working stress of 0·28 the strengths at 90 days, which are about 1½ times those at 28 days, consequently they allow about 0·42 of the strengths at 28 days.

The L.C.C. strengths at 28 days do not bear a fixed relation to that at 4 months, but they vary from ⅔ in the case of 1 : 2 : 4 concrete to 11/15 in the case of 1 : 1 : 2 concrete. The working stress (*c*) [paragraph 42 (*a*)] is consequently from 0·375 to 0·34 of the strength at 28 days.

According to the author's formulæ the working stress (*c*) [equation (1)] is 0·33 of the strength at 28 days.

The American Committee allow for members under flexure 0·325 of the strength at 28 days.

There is, in the author's opinion, no justification or necessity for two values for the grip or adhesion stresses, and he would suggest that the value of 100 lb. per sq. in. equally covers both cases.

The "adhesive" resistance, when there is also an anchorage, is an indeterminate quantity, and, with effective anchorage of any sort, it cannot be doubted that stresses very much higher than 100 lb. per sq. in. would produce no injury.

Paragraph 43 allows a working tensile stress of 16,000 lb. per sq. in. on mild steel, without regard to its use in direct or diagonal tension.

The limit of 16,000 is, in the author's opinion, somewhat high for use in calculations with respect to diagonal tension, as in this case the actual stress on the reinforcement cannot be accurately determined.

It is suggested that for diagonal tension calculations, ¾ the stress allowed for direct tension is sufficient, which would reduce the working stress for diagonal tension to 12,000 lb. per sq. in. for mild steel.

For compressive reinforcements in hooped columns the limit of working stress should be half the stress at yield point, which would be about 16,000 lb. per sq. in. for mild steel.

It is suggested that when high tensile steel is used the allowable working stress might be increased to 20,000 lb. per sq. in. either in direct or diagonal tension, and that when used as compressive reinforcement in hooped columns the limit of working stress should be half the stress at the yield point.

It is also suggested that specification requirements for high tensile steels should be included in all reinforced concrete regulations.

Paragraph 54 imposes values for the coefficient "*m*," as shown in Table V., based on the working stresses given in paragraph 42 (*a*) and on the stresses suggested by the author as obtained from equation (1).

TABLE V.

Proportions of mixture.	Value of "m."	
	Based on stresses as given in paragraph 42 (*a*).	Based on stresses as given by equation (1).
1 : 2 : 4	15	15
1 : 1$\frac{2}{3}$: 3$\frac{1}{3}$	13·846	13·33
1 : 1$\frac{1}{3}$: 2$\frac{2}{3}$	12·857	11·66
1 : 1 : 2	12	10

For hooped columns the value of "*m*" would vary with the form and spacing of the lateral bindings and with the ratio of the volume of the lateral *bindings* to the volume of the hooped core.

This regulation must have the effect of considerably adding to the complexity of the calculations, and in the case of hooped columns will render the design a most tedious and troublesome matter.

The modulus of elasticity of concrete, used in assessing the value for "*m*," should be its instantaneous value at the working (or even a somewhat higher) stress, whereas most authorities give the initial value.

When deciding on the value to be assumed for the coefficient "*m*," it must also be borne in mind that there are other factors to be considered as well as the moduli of elasticity of the concrete and steel. The effect of loading and unloading is one such factor.

It is contended that there is not sufficient justification for insisting on a varying value for the coefficient "*m*" decreasing with stronger mixtures, and that the value of "*m*" for use in the design of hooped members need not be less than that used in the design of ordinarily reinforced members. There appears to be no justification whatever for providing that the value of "*m*" shall be obtained from equations such as those given under paragraph 54, which are based on no recognised data, being purely empirical, and which give values which, in some cases, are not even whole numbers.

It is also contended that since the modulus of elasticity of concrete in compression is, at the best, a doubtful quantity, and as other factors must be taken into account when deciding on the value of "*m*," a constant value of 15 for this coefficient is quite sufficiently accurate for the purposes of calculation, and that the assumption of this constant value is justified, under the circumstances, by the simplification it allows in the necessarily intricate calculations required for the design of reinforced concrete members.

In the case of paragraphs 61 and 62, dealing with the use of compressive reinforcements in beams and similar members, it is extremely doubtful whether the spacing of the anchorage specified in 61 (*b*) is really necessary in the case of rectangular beams, and, in any case, the second proviso, that the anchors shall not be further apart than 16 times the least diameter of the anchored bar, is not justified, since the compression bars can never be stressed as highly as $m \times c$ lb. per sq. in., and in the majority of cases will only be stressed to $\frac{2}{3}$ ($m \times c$) or slightly more. (These values are in the case of 1 : 2 : 4 concrete 9,000 lb. per sq. in. and 6,000 lb. per sq. in. respectively.)

The anchorage is only required to resist the lateral deflection of the reinforcing bars, and the security against this action would, in the author's judgment, be provided by anchorages considerably further apart than the distance insisted on under this regulation.

It is suggested that in rectangular beams the anchorage should not be further apart than 24 times the least diameter of the anchored bar.

In the author's opinion the resistance of 16,000 lb. per sq. in. for a mild steel compressive reinforcement as specified under paragraph 62 is too great, and should be reduced to 14,000 lb. per sq. in. at the most, and a similar reduction be made to the resistance of the tensile reinforcement.

The distance apart of the anchorages specified under paragraph 62 (*b*) could, in the author's opinion, be greater than eight times the least diameter of the anchored bar, as the direct stress on the compressive reinforcement would not cause material lateral deflection with anchors at much greater distances apart.

The limit of 6 in. for the spacing is a very conservative assumption. The author would suggest that the spacing, in this case, might reasonably be extended to a distance equal to twelve times the least diameter of the anchored bar.

In paragraph 64 the first alternative appears to be unnecessary, and the author fails to see what authority there can be for limiting the shearing resistance to the compressed area of the web, since the shearing resistance must continue from the neutral axis to the surface of the tensile reinforcement in order that this reinforcement may act in the resistance to flexure. In fact, the maximum unit shearing stress on the concrete exists from the tensile reinforcement to the neutral axis and reduces from maximum at the neutral axis to nil at the centre of the compressive resistance.

The restriction as to spacing of the diagonal tensile reinforcements under *paragraph* 67 (*a*), while it complies with the best practice and is certainly advisable in the case of T-beams, does not appear to the author as a justifiable regulation in the case of rectangular beams where the sharp increase in the shear at the plane of junction of the web and a flange does not occur.

The author fails to see the reason for the restriction as to the effective depth of slabs, under *paragraph* 72, which appears also to be merely an arbitrary ruling.

Provided a floor slab satisfies the regulations as to resistances, cover to reinforcements, and relation of depth to span, there appears no reason for placing an arbitrary value on the effective depth.

In *paragraph* 78, dealing with distribution bars, it is not by any means clear how the imposed values have been arrived at. Why, for instance, is the cross sectional area limited to 0·08 per cent. of the effective cross sectional area of the slab?

In actual practice it is quite usual to use $\frac{1}{4}$-in. rods spaced 12 to 18 in. apart, according to the circumstances of the case, where there is no actual necessity for a two-way reinforcement.

The width of flange permitted in the calculations for T-beams under *paragraph* 82 (*a*) and (*c*) is considerably less than has hitherto been admitted to be perfectly safe limits in the best practice, and one can see no justification in reducing, without an ample reason, limits which have always proved safe and reliable for conservative design.

Paragraph 82 (*a*) should be $\frac{1}{3}$ effective span of the T-beam, and paragraph 82 (*c*) should be 15 times the thickness of the slab.

In *paragraph* 83 the limiting width might reasonably be increased to at least six times the thickness of the slab. The second proviso might stand, providing the limits under paragraph 82 were increased as suggested.

Paragraphs 87, 88, 113, 116, 117, and 121, showing methods of calculation, should not, in the author's opinion, form part of the regulations.

The L.C.C. regulations are, in the author's opinion, unnecessarily restrictive with respect to the design and construction of pillars and struts, and, if they are to be complied with, the use of either ordinarily reinforced or hooped compression members will only be economically possible in rare instances.

The regulations provide that the effective diameter or that to the outside of the outermost longitudinal reinforcement shall be used in all calculations for compression members, whether reinforced in the ordinary way or hooped; the working stresses being those given in paragraph 42 (*a*) or the increased value "*i*" allowed under regulation 115.

This provision is unnecessarily restrictive on the employment of columns reinforced in the ordinary way, and it is strongly urged that the resistance of reinforced concrete compression members of this character should be permitted to be calculated on the outside sectional area with working stresses on the concrete 5/6 of those given in paragraph 42 (*a*) as altered according to the author's equation (1).

The restrictions, with respect to the spacing of bindings, imposed under paragraph 105 (*a*) are excessive in the case of ordinarily reinforced columns.

The bindings are in this case mainly required to prevent lateral deflection of the longitudinal bars, and the limits of spacing, in the author's opinion, might safely be sixteen times the diameter of the least longitudinal bar.

The restriction of the spacing to 6/10 the least *effective* diameter of the member is justifiable in the case of hooped members, as in this case the bindings serve as a lateral support to the concrete.

Paragraph 105 (*b*) should merely specify that, in ordinarily reinforced members, the spacing of the lateral bindings shall be half that provided for under paragraph 105 (*a*) for a distance at the ends equal to 1½ times the *outside* diameter.

In the case of a hooped member no such restriction is necessary.

Paragraph 107 should only apply to hooped members, as it is a provision applying to this class only.

The limitation in *paragraph* 109 is one that should only apply to hooped members and the limit in this case should, in the author's opinion, be reduced to 0·08 per cent., as this figure has been generally accepted and has proved to be adequate.

The lower limit of ½-in. diameter bars, provided for in paragraph 108, is quite sufficient to cover the control of the sectional area of the longitudinal bars in columns reinforced in the ordinary way.

A statement might be added to paragraph 118 to the effect that intermediate values for the spacing factor may be obtained from the equation $s = 48 - 8c\frac{p_b}{d}$

Paragraph 119 is, in the author's opinion, an unnecessary restriction on the design of hooped members, and this class only can be affected by this paragraph.

The second report of the Joint Committee on Reinforced Concrete, under the auspices of the Royal Institute of British Architects, suggests a limit of $(0{\cdot}34 + 0{\cdot}32\,f)\,u$ which gives $\frac{1}{2}u$ for rectangular laterals, $7/12u$ for independent circular hoops and $\frac{2}{3}u$ for helical bindings—*u* being the ultimate compressive strength at three months which has values comparable with the four month values of the L.C.C. regulations.

The author suggests that the limitation of $(0{\cdot}34 + 0{\cdot}32f)\,u$ given above will be perfectly safe, although somewhat higher than that allowed by the French Government, that for helical bindings being 2·64 times the working stresses given by the equation paragraph 42 (*b*) or by equation (1), or 0·88 times the compressive strength at 28 days given by equation (2).

The limitations on the length of columns and the loading to be allowed on long columns as provided under paragraph 122 are unnecessarily severe.

It is suggested that the limitation for calculation as short columns should be 18 times the least diameter of the core in case of ordinary reinforced members and 15 times the least diameter of the core in the case of hooped members.

It is well known that the lateral deflection of hooped columns is greater than that of ordinary columns of equal strength, and consequently the calculation as short columns should be restricted to a less comparative length for hooped than for ordinarily reinforced members.

The author fervently hopes that the general question of the restrictions imposed by the L.C.C. regulations on the design of compression members will be adequately dealt with during the discussion, as he feels convinced that this section of the regulations should be considerably modified at an early date, if the use of reinforced concrete columns in the County of London is not to be unjustly and severely restricted.

In *paragraph* 180 the author suggests that the mortar mixture should be of the same proportions as the cement and sand in the concrete which is being used.

The limit of temperature specified in *paragraph* 182 is, in the author's opinion, higher than necessary, and he considers that the concreting operations might be allowed to be proceeded with until the temperature fell to 35° or 34° Fahr. without fear of harmful results, as freezing would not actually occur until 32° Fahr.

DISCUSSION.

Sir Henry Tanner, C.B., I.S.O., in moving a hearty vote of thanks to Mr. Marsh, said it seemed to him very important and very desirable that a sort of Standing Committee should be established to bring up all the points, so that they could be considered by the County Council in due course. There were many things in the Building Act which might also be dealt with in the same way. He was Chairman of the Institute Committee, and afterwards of the Joint Committee, and their reports formed the basis of a great deal that had happened since. One thing which had struck him very forcibly on several occasions was that for the strength and stability of concrete a factor of safety of 1 to 4 was altogether too much. He thought it ought to be very much less. In his experience floors had borne very much heavier loads than they were estimated for without any deflection.

Mr. W. G. Perkins (***District Surveyor for Holborn***) observed that with regard to the percentages which might be deducted from the live loads, if they were permitted in this country to erect buildings of the height to which they were raised in the United States, there might be a great deal in Mr. Marsh's argument, but in this country the height of buildings was limited, and after they came down two or three stories any advantage that they might get from this discounting of live loads would not amount to very much.

As to strength or stresses permitted by the Regulations not being high enough, when Mr. Marsh was acting for an authority like the Water Board, in carrying out any work he could have a competent inspector, select his materials, and have the very best, and he could do everything possible to secure perfect concrete being made and used, but when it came to a district surveyor he could not do that. Nine out of ten buildings in his district were erected by speculating builders, and they could not permit high stresses to be placed upon the concrete that those people made. It was largely for that reason that these comparatively low stresses had been inserted in the Regulations.

Mr. Marsh explained that the stresses which he considered too low were those for the stronger concrete, and Mr. Perkins' remarks applied just as much to the 1 to 4, to which he saw no reason to object. All he said was, put them on the same footing.

Mr. Perkins said that, after all, these Regulations were for speculating builders, and not for the architect or engineer who wished to erect a building in the best possible way. It was far better in drafting Regulations like these to keep them as simple as possible. They did not want a series of numbers or numbers entailing decimal points; a good round number like 15 much simplified the calculations and made the work much more easily supervised. With reference to the suggestion that the Council's Regulations were unnecessary in the matter of pillars and struts, if Mr. Marsh had seen some of the work commenced in his district he thought he would not have stated that.

Mr. Alban H. Scott said this was the first set of official Regulations in England on reinforced concrete. The London County Council had not a free hand; they had practical men, theoretical men, chemists, and every sort of person to please, and in spite of what had been said about the London County Council and the Local Government Board, he thought they were honestly to be congratulated on what they had produced in the way of Regulations. The strength of reinforced concrete did not depend upon the engineer or the designer, but upon the British labourer. Reinforced concrete was about the only material used in building which could not be seen and inspected in its actual finished state. They knew nothing at all about the strength of the actual structure. During the period the Regulations were being discussed by the Committee of that Institute the principle he went upon was to try to keep down what he would call the excessive loading desired by some. Mr. Marsh objected to the length of the cantilever being limited to five times. It would be rather interesting to know if in ordinary building work any cantilever limited to five could not comply quite easily with that condition. He gave approximately one-tenth of the whole Paper to the strength of materials failing under tension. He (Mr. Scott) was of opinion that every material, no matter what, failed under shear and not under tension. The strength of concrete depended very largely on the strength of the aggregate as such. Concrete made of granite was very much stronger than concrete made of ordinary gravel, and the strength of granite concrete depended upon the strength of the granite itself. It was inviting disaster to permit additional stresses on steel to half the yield point. The question of the shrinkage of concrete in setting he thought was a subject which required a good deal more investigation. Reinforced concrete structures were accepted by the London County Council as fire-resisting structures, and accordingly the question of the design should be considered with more regard to the question of fire. Reinforced concrete as used was not necessarily always an excellent fire-resisting material. On the other hand, they could not use coke breeze for reinforced concrete. So as to make reinforced concrete more complete or more in harmony with the London County Council's feelings as to fire resistance, he thought all steel should be covered by two inches of concrete whether in slabs or columns or buildings.

Mr. Ewart S. Andrews, B.Sc., thought the whole difficulty with Regulations of this kind was that the more detailed they were made the more necessary it became that economical designs should be encouraged. They should not be of too restrictive a nature. It was essential that some detailed Regulations should be enforced. The fact that these Regulations had official sanction and the authority of the Local Government Board made it extremely difficult to depart from them, even when experience showed that further latitude might be allowed. In order to prevent unsafe construction there was a tendency always to err on the safe side, and by an accumulation of this giving the benefit of the doubt to the safe side they could easily get to a condition of affairs in which real economy was in danger of being sacrificed and in which originality in treatment and design tended to be at a discount. One way of getting out of this difficulty, and which would encourage development, would be to give the option either of complying with these Regulations or else submitting the structure to a test load which would ensure a satisfactory factor of safety before the building was passed. The Regulations could and should be modified, but the alternative treatment which he suggested would meet a great many cases which arose. He heartily agreed that requirements for high tensile steel should be embodied in all reinforced concrete Regulations. It had been a moot point for some years, but experience had shown that many higher tensile steels were quite suitable for reinforced concrete work, and it seemed ludicrous not only to prevent their being used to full economy by increasing the permissible stress, but also to prohibit their use at all. He did not want to minimise the necessity for securing safety in construction. The great thing to keep in mind was that efficiency was the first point to consider. At present, of course, they were forced to consider economy in material. He was not sure they were allowed to observe it to the extent that they should, because in addition to there being a shortage of steel there was also a shortage of brains. If they realised that ultimately everybody's interest would be best served by using their material in the most economical way possible, they should make a great advance as they progress in the scientific development of their subject, and ultimately everybody would benefit by the use of material in its most economical form.

Mr. E. Fiander Etchells, A.M.Inst.C.E., said the authorities were well aware of the necessity for constant revision of the Regulations. In 1909 they decided to go in for Regulations for reinforced concrete instead of an Act of Parliament, because Regulations were more easy to alter from time to time. On June 24th, 1913, they reported as follows :—" Speaking generally, the alterations are chiefly changes in form only, though in some instances they render the Regulations somewhat more onerous than those originally adopted. Any increase in the standard of stability may evoke criticisms, but as the use of reinforced concrete in building work is a modern development, it is in our opinion expedient to accept the modifications so that the Regulations may speedily come into force and ensure safety in the employment of this method of construction. If during the next few years experience shows that the Regulations may with advantage be made less onerous, there should be no difficulty in modifying them accordingly." They would see, therefore, that they were prepared to consider amendments, but they had also intimated that they would consider those amendments when the four Technical Institutions were agreed among themselves as to what the Regulations should be. So far, unanimity of opinion had not been obtainable. If in practice they did not want to design a cantilever having a length exceeding five times its depth or a floor of less than three inches in thickness, where was the practical hardship? Three inches was the minimum thickness of slabs; five inches was the minimum thickness of fire-resisting floors.

Mr. Marsh : Surely you would not allow a building to be put up that was not fire-resisting?

Mr. Etchells said the answer, strange as it might appear, was "Yes," if Mr. Marsh had his way and made no restriction as to the depth of floor slabs. Mr. Marsh had referred to decimals as a modular ratio. He (Mr. Etchells) hoped that no surveyor would hold a job up because a modular ratio came out as a decimal. He hoped they would work to the nearest round number; he did not think the authorities would take any proceedings against them because they neglected a decimal on a matter which Mr. Marsh himself admitted was exceedingly uncertain, and on which they could not lay down a definite law.

The President said it was quite evident from the discussion that many gentlemen did not agree with Mr. Marsh, but that did not diminish in the least degree their indebtedness to him for having brought forward various points upon which it was possible that economy might be introduced by modifying the Regulations. He certainly echoed the suggestion of Sir Henry Tanner that a Committee should be appointed to consider not only what he might call the scientific investigation and thought that had been given to this subject, but also the results of the actual experience gained from the administration of these Regulations during the few years they had been in force, and if such a Committee were formed and they were able to persuade various technical societies who had part control over this matter that certain improvements might be introduced, he thought a great deal of this would be due to Mr. Marsh's endeavours to force the matter to the front.

THE LECTURER'S REPLY.

Mr. Marsh, in reply, said he failed to appreciate Mr. Perkins' attempt to justify what they might call the theoretical strictures of the Regulations by reason of the faulty construction. Surely the two things were entirely apart; they must either regulate for their construction by itself and guard against it in that way instead of providing unduly strict regulations with regard to design in order to counteract the faultiness in construction. It was necessary to control the jerry builder, but why control him by having restrictive regulations with respect to design, he could not see. On the point of the length of the cantilever, he did not object to it being five times the effective depth. There was no reason why a cantilever should not be dealt with in exactly the same way as a beam as far as the effect of length went. Mr. Etchells' answer to one of the points raised was the typical answer of a framer of regulations—"We may now proceed to use the Regulations as they are printed." That was the *non-possumus* attitude. They would not consider it any further; they would proceed with the Regulations. He maintained that there was no reason for treating the richer mixtures of concrete in a different way from the inferior qualities. Construction was one thing, and design was another. He could not see why, because a man was going to put in bad work, they should tell the man who was designing the structure he must make it far too strong for the job.

CORRESPONDENCE.

To the Editor of Concrete and Constructional Engineering.

Sir,—As a constant reader of your interesting Journal, I should like to traverse some of the statements made by Mr. Potter in " Concrete Simplified " (Feb. issue).

Of course, Mr. Potter may be referring to mass concrete in foundations and walls, where perhaps excellence of work does not so much count, whereas I refer to concrete in smaller and lightly designed articles.

Page 94, par. 4. He states " slag makes one of the best aggregates." I beg to differ. He admits it contains sulphur, and sulphur, chemists tell us, is a deadly enemy to cement. Many failures have arisen due to its use, and it is excluded by all rigid building bye-laws and specifications. It is also a deadly enemy to steel and therefore should not be used in connection with it.

Some years ago concrete made with slag was used in connection with steelwork on a very large main line bridge on one of the principal English railways. After the bridge had been completed a short time examination showed serious corrosion where the slag concrete touched the steel, and it all had to be pulled out.

Coke breeze (page 95, par. 2). One of our principal testing engineers told me that of all unsatisfactory materials brought him to test concrete made of breeze and cinders was the worst. While there may be situations where it is advisable to use it, it must remain a suspect material.

Boiler Ashes (page 95, par. 6). Drivers do not " eke out their fuel by using stone," as stated. With some coal it is necessary to use brick ends or stone to keep the fuel from clinkering on the bars.

Lime Concrete. I have used hundreds of tons of lime concrete which is to-day as hard as a rock, but I do not advocate nor do I think it advisable or necessary to use cement with it. Cement if properly made should contain no free lime. Why, then, add lime to it?

There is much that is excellent in the article, but as an engineer of thirty-five years' experience I must protest against these misstatements. It is the failures due to the use of such wrong materials that give concrete a bad name. In spite of its general adaptation there are even to-day engineers in high positions who look askance at it and will not use it more than they can help, and we must, by eliminating all failures, patiently wear down their opposition. The best way to do this is to use nothing but the finest material allied to skilled design and workmanship.

Yours truly,

William Marriott, M.Inst.C.E.

The Preservation of Iron in Concrete.

To the Editor of Concrete and Constructional Engineering.

Sir,—The very valuable information on the above subject which you published in a recent issue confirms my experience on this difficult subject.

Steel-reinforced concrete is of such recent origin that the data are scarce. The importance of preventing dampness—not only from rusting the steel but from disintegrating the cement by the action of wandering electrical currents—is not sufficiently recognised.

I first had my attention drawn to the latter danger several years ago by the engineers of one of the largest British Government Departments. They were desirous of protecting the underground work of their telephone and telegraph departments. Several difficult tests were made by the department engineers, both in the laboratory and in actual work, with the result that Pudlo is now regularly specified by them to waterproof the concrete or the cement renderings.

The data I have collected on electrolysis are very instructive, and comprise opinions and facts from many countries and from the most eminent experts.

For instance, the American Society of Civil Engineers, in conjunction with three other associations, set up a joint committee on concrete in 1903, and in 1916 a full report was published. While the result of their experiments agree with the matter you have published, their report is more voluminous and will be of interest to most architects and engineers.

I shall be glad to give any further information I possess on this subject to any of your readers.

Yours faithfully,

J. H. Kerner-Greenwood.

NEW BOOKS
AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

Bridge Engineering. By J. A. L. Waddell.

London: Chapman & Hall, Ltd. In 2 vols, 23/- net each.

There are not many good things that we can attribute to the present war, but this book is one of them, for the author tells us that but for the paralysis of bridge engineering consequent upon the war he would never have found the time to write it. Judging from the amount of work put into the book by Mr. Waddell and his assistants, all this being gone into in unusual but very interesting manner in the preface, these two volumes ought to contain more useful information upon bridge engineering in their two thousand one hundred odd pages than anything that has previously been attempted; and so they do. It is impossible in a brief notice of this kind to give an exhaustive review; even to give the list of chapter headings, of which there are seventy-nine, would use up all the available space at our disposal. We will instead give a brief idea of the scope and treatment of the book.

The book is the grown-up form of the child that was born under the name *de Pontibus* more than eighteen years ago, and has grown in stature and knowledge every time that it has appeared in a new dress; this time it has come to full maturity.

The ordinary treatment of the determination of stresses in bridges is not given, as the author believes that such treatment is already to be found in satisfactory form in the existing text-books.

We will direct attention to some of the features of the book which are of great value and which are not usually treated. First among these may be mentioned Chapter LII. on "Æsthetics in Design"; the following quotations from the precepts laid down indicate the trend of the author's views:—"A structure must be in harmony with its environment and not appear as an intrusion thereon"; "Mere ornamentation generally affronts the sense of harmony and fitness"; "Each part of a structure should be treated in such a way that its function therein shall be apparent and emphasised according to the importance of that function"; "The present steel-trussed bridge is inherently ugly, but with the further perfecting of the science of bridge design and a recognition of the fact that beauty is an aim and not an accident of growth æsthetic forms will be evolved."

Chapters LVII. and LVIII. deal respectively with "Estimates and Office Practice" and contain much valuable information, which is the result of long experience and which engineers seldom are willing to make public. Other valuable chapters deal with "Specifications in General," "Contracts," "Reports," "The Promotion of Bridge Projects," "Bridge Engineering Fees," "Some Business Features of Bridge Engineering."

On the subject of "Bridge Engineering Fees," which, of course, the author contends to be too low, he gives the following excellent advice to each individual engineer for advancing the status of the engineering profession. "Let him refuse to lend himself to every endeavour on the part of his clients or employers to keep down the salaries of his subordinates; but, on the contrary, let him insist upon their compensation being advanced as their experience and the value of their services increase. Let him also refrain from envy and ill-natured remarks when he learns that some other engineer in his own class has received advancement or secured a large fee . . ." The book concludes with a glossary of technical terms occupying 240 pages.

The author expresses in the preface the hope that when his time comes to pass on to the beyond the profession will deem him worthy of the Colorado epitaph, "He done his level damnedst; no angel could do no more." We believe that he done.

THE Book on Housing and other Problems

Concrete Cottages

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"A volume of exceptional interest and great practical usefulness."

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"A very useful and complete book."

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"Altogether the book, which contains some 150 illustrations, has been exceedingly well edited."

Municipal Engineering.
"A well printed, liberally illustrated, and informative volume."

Contract Journal.
"The author enters into every detail most thoroughly and the sketches of construction are clear and good."

Estates Gazette.
"The method of constructing from Concrete small dwellings, garages and farm buildings is exhaustively described."

British Architect.
"The study of such a book is well worth while."

Concrete & Constructional Engineering.
"This book has been prepared and published for the purpose of giving useful and reliable information as to the use of concrete."

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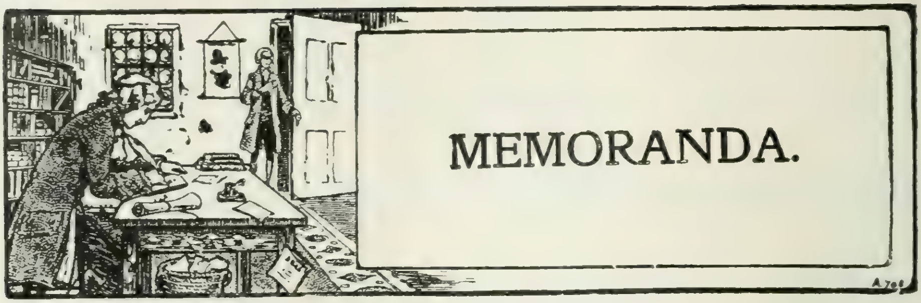

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Silo Staves for Farm Buildings.—On a farm building near Elgin, Ill., concrete silo staves of a pattern which, set horizontally, provides in its rib an overhung joint which is weatherproof, are used extensively for buildings. In erecting the walls forms with edges cut to conform to the staves are set up and vertical rods placed for reinforcement. The staves are set in position with their ends projecting slightly inside the stud form, which is poured full of concrete. A poultry house and a hog house were erected on the above farm of this construction, and not only the buildings but the runs are of stave construction. The gates to all pens are of plank arranged to slide through a slot in the top member of the fence and in grooves left in the concrete studs. Gates inside the building are arranged in a similar way.—(*Concrete,* U.S.A.).

A Novel Form of Reinforced Concrete.—Concrete Houses in the Philippines.—Concrete houses in the Philippine Islands have been erected by using a concrete reinforced with woven mats of bamboo, and the concrete is composed of cement, sand and rice husks. This type of house has been developed by the Philippine Health Board to replace the primitive bamboo and thatch dwellings.

The Working-Class Home.—Some time ago the Housing Sub-committee of the Women's Labour League invited the working women of the country to answer a series of eighteen questions contained in a circular as to what are the defects of the present type of house and the auxiliary advantages that are necessary to make the working-class home all that a house should be.

Mrs. Sanderson Furniss, the secretary of the Housing Sub-Committee, has received a volume of interesting replies, particularly to the questions "What is wrong with your house now?" and "What sort of house do you want in the future?"

Generally the replies indicate a desire for a centrally heated self-contained cottage with three bedrooms, sitting-room, eating-room, and self-appointed scullery-kitchen, with an electrical installation for cooking. The practice of making the bathroom a part of the scullery is universally condemned. There must be a separate bathroom. Throughout the replies runs the plea for light and air, large gardens, communal playgrounds for the children, and sweetness and cleanliness in the scullery. Flats are not popular.

Seaside Baths.—To give some sort of architectural dignity to seaside bathing establishments was one of the suggestions put forward by Mr. J. W. Cockrill in a paper read before the Town-Planning Institute on "The Development of British Watering Places After the War." Was it necessary, he asked, that if an indoor swimming bath were to be attempted it should be covered with a railway station roof in miniature? A few recent erections had been put up in reinforced concrete, a material which offered at reasonable cost the opportunity of producing something more substantial and dignified than the methods of construction now in use. In designing one of these establishments in the near future something on the lines of the Roman baths should be attempted, and the successful architect at work on it might have in his mind as models some of the grand designs to be found in Piranesi's etchings.

Concrete Vaults as Cisterns.—It often happens that in building a vault or a concrete-lined cistern it is desirable to use as little lumber as possible. This can be accomplished by using four wide planks, tacked together in the form of a frame, the size of the inside of the opening desired. The bank is trimmed to the proper size or the outside form and the plank frame set in position at the bottom of the hole. Semi-wet concrete can then be rammed in place and the forms raised to nearly the width of the plank and again filled. If the proper mixture is used and care exercised in placing, a pit 3 ft. or 4 ft. can be lined, without danger of the concrete slipping. If it is desired to make this waterproof it can be done by plastering on the concrete which this method has left rough and in shape to make an excellent bond.

Improved Concrete Block Lining for Pit Shafts.—We reproduce the following particulars and illustrations regarding new concrete shafting which appeared in the *Colliery Guardian*:—Mr. Frederick Walker, sinking contractor, Doncaster, has been granted patent rights for an improved form of concrete block for lining pit shafts and similar purposes. The block is of the stepped T-shaped

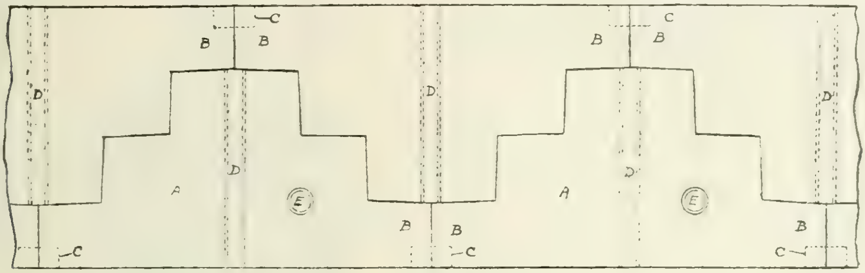

FIG. 1

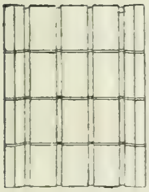

FIG. 2.

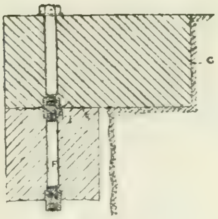

FIG. 4.

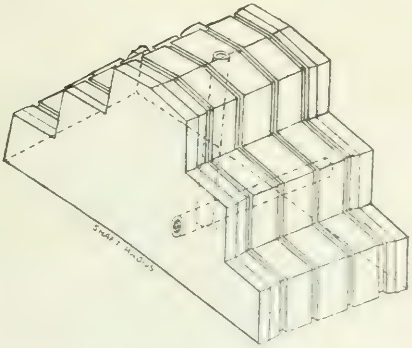

FIG. 5.

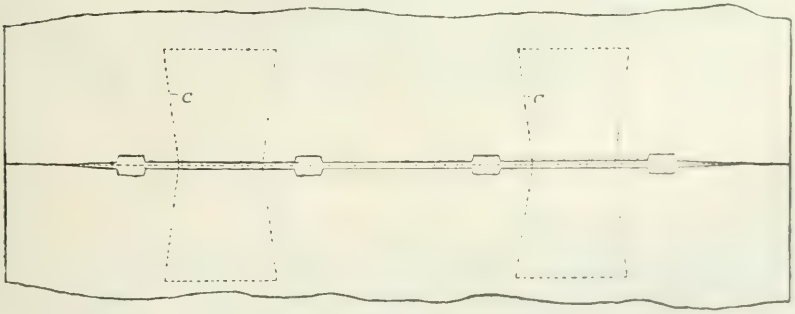

FIG. 3.

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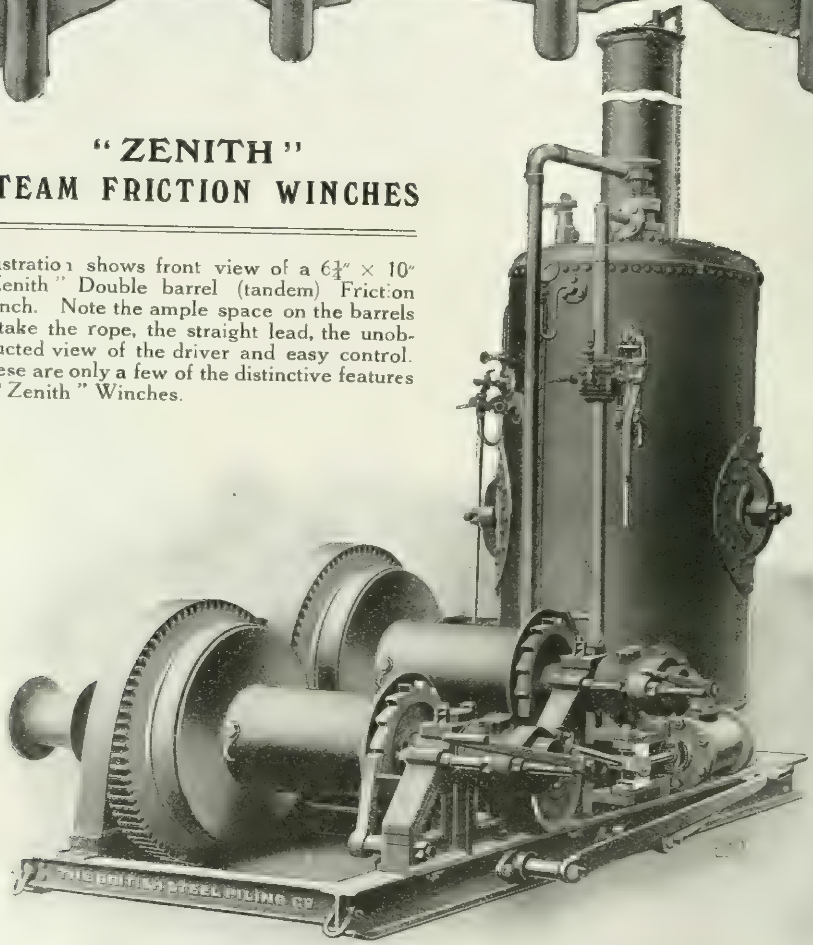
Illustration shows front view of a 6¼″ × 10″ "Zenith" Double barrel (tandem) Friction Winch. Note the ample space on the barrels to take the rope, the straight lead, the unobstructed view of the driver and easy control. These are only a few of the distinctive features of "Zenith" Winches.



DOCK HOUSE, Billiter Street, LONDON, E.C.

type, in which the bond is obtained by inverting alternate bricks. Hitherto blocks of this type, as used for straight walling, have been constructed with normal faces to the steps, in such a manner that they have vertical and horizontal joints between the steps of adjacent blocks. In one type the steps have been provided with inclined jointing faces, such incline, whether longitudinal or transverse, being arranged in an inward direction so as to form an acute angle between the jointing faces of each step, for the purpose of obtaining a locking effect between the faces of adjacent blocks.

The present invention is characterised mainly by the vertical and horizontal faces of the steps being slightly tapered in an outward direction so as to be thick at the neck and narrowing down towards the nose, thereby avoiding any weakness across the neck either in a vertical or in a horizontal direction, and at the same time facilitating both the moulding and laying of the blocks. This last would more particularly be the case when the blocks are used for shaft lining—the principal application of the invention—in which case the wall may require to be built either upwards in the ordinary manner or from the top downwards. A further feature of the invention consists in the combination with the outwardly-tapered stepped block of a parallel uniform and laterally-connected series of flat and approximately rectangular inter-grooves on all the jointing faces, vertical and horizontal, of the stepped block. Horizontal and central vertical blowpipes are moulded in each block, through which liquid cement is forced in to fill up the spaces behind the blocks and the groove joints between the blocks.

The form of construction will be better understood by reference to the line drawings, of which *Fig.* 1 and *Fig.* 2 show respectively a front and end elevation of two complementary courses of the blocks. *Fig.* 3 is a cross-section on a larger scale, showing the laterally-connected flat-grooved joint between two blocks. The blocks, it will be noted, are all the same shape, and are such that when two blocks A, A, are laid together, an intermediate inverted block B will fill up the space between them. The main horizontal joints are locked by a series of iron dowels, for which space is provided at C, when moulding the blocks. The stepped grooved joints are filled up by forcing liquid cement through the blowpipe D, which is placed centrally in the mould of each block so as to be readily accessible and discernible. The cement for filling in the space between the walling and outer lining is forced through the pipes E.

Fig. 4 shows the proposed arrangement when it is necessary to build the shaft lining from the top downwards. In this case the lining wall is reinforced by the bolts F, which are connected by ferrules I, and passed vertically through holes moulded in the blocks so as to afford means of continuously connecting the successive courses. Provision is also made for further strengthening the wall by the employment of courses of wider blocks, as at G. *Fig.* 5 is an isometric view of the blocks.

The West Quay of Madras Harbour.—A paper was recently read before the Institution of Civil Engineers on this work. The authors of the paper were Sir Francis J. E. Spring, K.C.I.E., and Mr. Hugh H. G. Mitchell, M.Inst.C.E. They describe how, at a cost of £200,000, 3,000 lineal feet of a quay, fit for vessels of Suez Canal draughts, has been constructed along the west, or shore, side of Madras artificial harbour. The quay in question has replaced the shelving, sandy shore and, by allowing dredging to be done, has enabled the Port Authority to enlarge the area of the enclosed harbour, available for shipping, from about 100 to about 200 acres. In other words, the shore half of the harbour, which before the construction of the quay was available only for small craft, is now available for vessels of Suez Canal draughts.

The quay is constructed mainly of granite cement concrete faced with granite masonry. It rests on about 70 double-aperture wells or monoliths, sunk to a depth of 55 ft. below low water, or to a depth of 23 ft. below the dredged bottom of the deepest berths. Of the wells 21 are 50 ft. by 28 ft., three are 44 ft. by 28 ft., 21 are 43 ft. by 24 ft., and 19 are 35 ft. by 20 ft. Besides these 64 deeply-sunk or regular wells, there are at each end a few smaller and shallower wells, where the quay crosses the rubble base of the old harbour breakwaters. Throughout the full length (2,980 ft.) of the quay its breadth on top of the wells is 24 ft. Its height above Indian spring low water is 12 ft. The wells are shod at the bottom with steel curbs weighing in the aggregate about 1,000 tons, made by local firms.

PUBLISHERS' NOTICES.

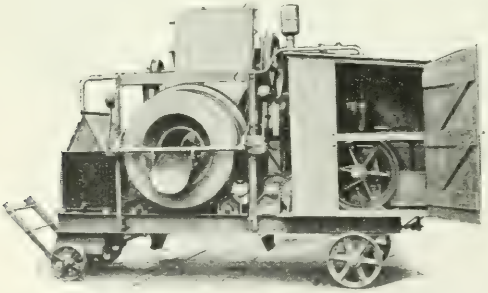
Messrs. James Selwyn and Co., 20, Essex Street, Strand, W.C.2, announce that they have taken over from Messrs. Whittaker and Co. the publication of Mr. Arthur Judge's books upon "Design of Aeroplanes" and "Properties of Aerofoils," and Mr. W. E. Dommett's successful book upon "Aeroplanes and Airships." They have ready for publication "A Primer of Engineering Science," by Mr. Ewart S. Andrews, and "Tables of Safe Loads on Plated I Beam Pillars," by Mr. Ewart S. Andrews and Mr. W. Cyril Cocking. These latter tables are calculated in accordance with the L.C.C. Steel Frame Act, and the price is 6s. net, post free from the publishers.

TRADE NOTE.

"The Welding Test"—A little booklet, entitled "The Welding Test," just issued by Barimar, Ltd., a London firm of scientific welders, which has built up an almost entirely new business of metal fusion for the repair or re-creation of fractured parts of machinery, deals interestingly with a highly technical subject in simple language. It shows how one firm has brought back into commission more than 20,000 British derelict machines now engaged on National Service. Many of the delicate processes by which complete metal fusion is brought about were practically German preserves in pre-war days, and the booklet will be read with interest by many people who follow approvingly the growth of British industries. To any reader who possesses fractured machinery a copy will be sent post free on application to Barimar, Ltd., 10, Poland Street, Oxford Street, W.1.

CHANGE OF ADDRESS.

The Trus-Con Laboratories, having had their Kingsway offices commandeered by the Government, have removed to 415-418, Bank Chambers, 329, High Holborn, W.C.1. (Tel. Holborn 360.)



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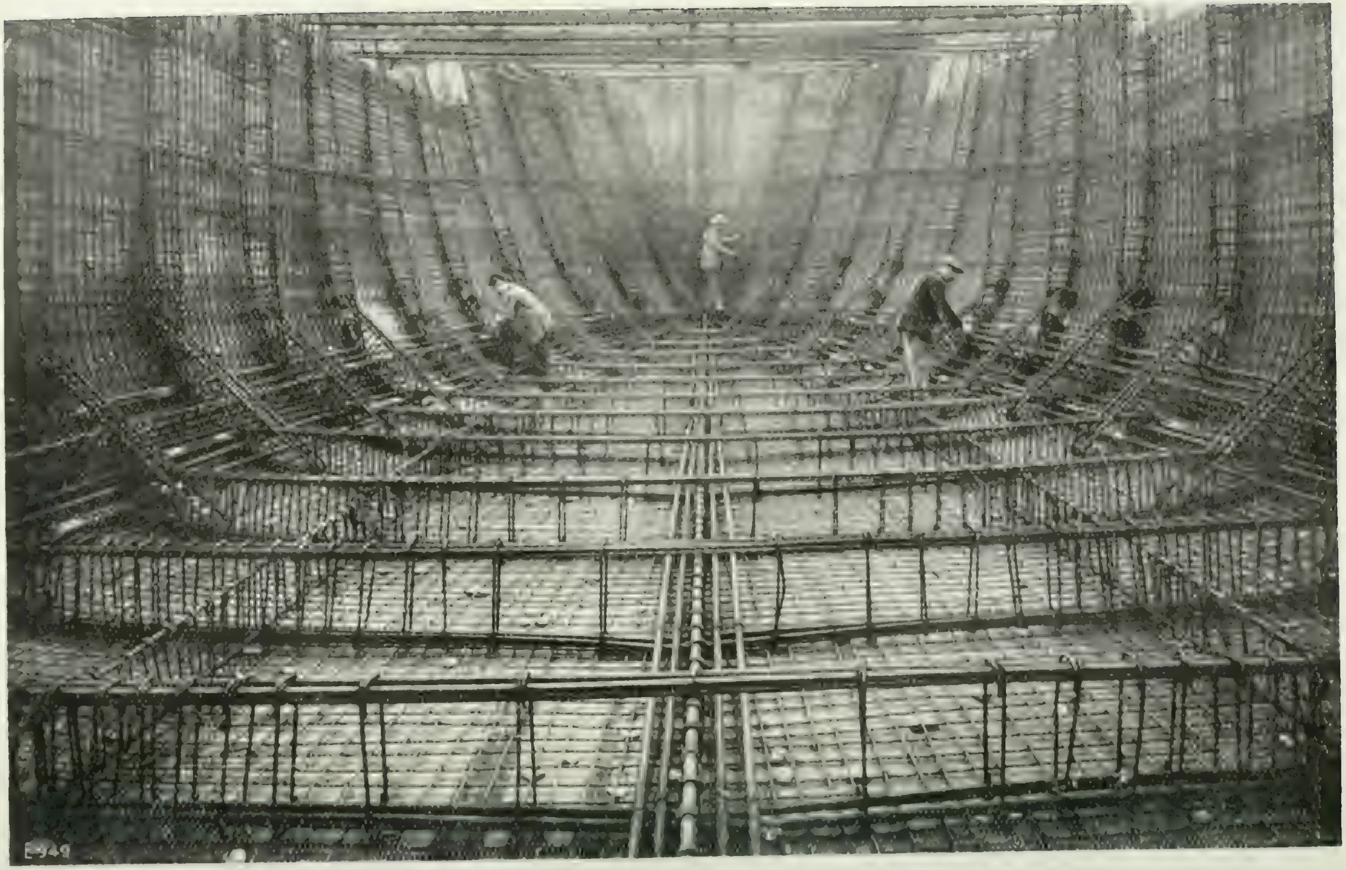


INTERNAL REINFORCEMENT OF CONCRETE VESSEL IN COURSE OF ERECTION IN SPAIN
(See page 210.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIII., No. 5. LONDON, MAY, 1918.

EDITORIAL NOTES.

CONCRETE FOR MINE SUPPORTS.

As far back as 1908 we strongly advocated the use of reinforced concrete for certain forms of ship construction, having seen excellent examples thereof on a small scale abroad. The idea was more or less ridiculed in this country, and only as a result of the war and the energetic efforts made in other European countries and the United States has it been realised in England that reinforced concrete ship construction had possibilities, and at last we see it announced that some sea-going barges have been launched in the United Kingdom, and that some sea-going cargo boats of the tramp steamer type are in course of construction.

It was in 1909 that, after careful enquiry, we also pressed the possibility, both practically and economically, of the use of concrete and reinforced concrete in mines, and we especially dwelt on the advantages of the reinforced concrete pit prop, which should be constructed to standard sizes to meet a large number of purposes in mines, although we never went so far as to say that every requirement of the mine could be met by concrete. It has again taken nearly a decade to make this country realise that there was something in our arguments, and the exigencies of the war are compelling us to find substitutes for the decreasing supplies of timber.

We have at last before us an authoritative memorandum on the use of concrete for mine supports, issued by Professor Knox for use at the South Wales School of Mines, Treforest, and dated January 18th, 1918. The direct cause of such an authoritative advocacy of reinforced concrete mine supports was primarily due to the scarcity of timber arising out of the war.

At the end of that exceedingly interesting memorandum Professor Knox mentions that our pre-war annual consumption of timber in mines was not less than 4½ million tons, of which four-fifths was imported from overseas. Even during the war, when timber has become so scarce and freightage so difficult, we have spent in 1915 no less than £4,700,000 on imported timber, and in 1916, £6,900,000.

We would strongly urge every colliery proprietor and manager to read Professor Knox's report, which we present in full in this issue. The time for the undue temerity as to the use of concrete and reinforced concrete has long passed in every part of the civilised world other than in the United Kingdom, where this temerity, more politely known as "conservatism," exists to a ridiculous degree. This, however, is no longer a time when conservatism in thought should be the order of the day, and whilst we may perhaps congratulate ourselves as being pioneers in the advocacy of reinforced concrete for ship construction, and also as having taken our fair share in the efforts to replace timber uses generally above ground by concrete and reinforced concrete, we also sincerely trust that one of the most conservative of all industries—namely, the colliery industry, both masters and men—may realise the advantages of concrete and reinforced concrete for underground work and the economy of its use both on the side of capital outlay and maintenance.

AIR RAID PRECAUTIONS AND CONCRETE.

In connection with one of the air raids that occurred during the past twelve months, and which resulted in a large number of casualties at some works that were being used as an air raid shelter, an ignorant public started disparaging the use of concrete as a protection against air raid bombs. It was argued that this particular building had had three concrete floors, and yet the casualties occurred.

It is about time that the circulation of foolish information of this kind should be stopped, as it prevents the necessary confidence being accorded to structures that well merit attention from the Air Raid Shelters Committee and others engaged in providing protection in the case of air raid attack.

No bomb pierced the three concrete floors in question, for the simple reason that the bomb dropped outside the building, and that the catastrophe was principally due, not to the concrete floors being pierced, but to one or more supports of the concrete floors in the building, which were of *brick*, being destroyed.

The problem of the strength of concrete did not come into question on this occasion.

CEMENT USED BY THE ENEMY.

One of those extraordinary popular outcries against the export of Portland cement to Holland was based on the possibility that British Portland cement had been used in enemy " pill boxes."

It is accordingly pleasant to be able to relate at last that, after some months of enquiry by a Government Committee, the facts, well known to anybody intimately conversant with the Portland cement industry, have at last been brought out—namely, that the cement labels that were found in these pill boxes were in respect of a Belgian brand of Portland cement which is being produced under enemy control in the occupied territory, and that no evidence whatever exists of the use by the enemy of the British Product.

It is also interesting to observe that the Committee of Enquiry advocate that this country should export Portland cement to Holland, where this material is largely required, and where the ill-advised commentaries on the matter appear simply to have resulted in the enemy being able to exchange one of their own commodities—viz., Portland cement—for foodstuffs from Holland, all to the detriment of the Allies in general, and the British industry in particular.

The concluding paragraph of the Report in question is as follows :—" The Committee feel bound to point out that the one-sided publicity which has unfortunately been given to the subject has created a rather widespread impression, which seems to have been shared to some extent by our troops in France, that the enemy derives assistance from the export of British cement to Holland. The Committee hope that their examination of the question and the conclusions which they have reached will suffice to dispel this impression."

A Reinforced Concrete Chalet.

REINFORCED CONCRETE IN SPAIN.

In the accompanying article we are able to present some interesting photographs of recent reinforced concrete work in Spain, including some additional particulars of the development of concrete shipbuilding in that country. For our particulars and illustrations we are indebted to Mons. J. Capmany, Chief of the Technical Bureau of the Société Construcciones y Pavimentos, Barcelona. From the large number of photographs sent us we present those most likely to interest our readers.—ED.

The Sociedad Anon. Construcciones y Pavimentos of Barcelona and Madrid has recently undertaken the development of reinforced concrete in Spain

In 1909, when Mr. Capmany, the engineer, and Mr. Juan Miro y Trepat, the managing director of this company, started to use reinforced concrete at Barcelona, the only example of such work in Spain was a starch factory built by Mr. Hennebique, near Barcelona, and some works in the north of Spain generally built by the State engineers. At first progress was very slow, but by perseverance in pushing the advantages of reinforced concrete as a building material the firm have now built a large number of works, many of which are of considerable importance. At the moment ordinary building is restricted on account of the war, which makes itself felt even in neutral countries. There are, however, no restrictions in building works of great importance.

The most important buildings constructed by this firm are of the following types :—

Electric Power and Lighting Station. Several electric power stations have been built. *Figs.* 1 and 2 show the exterior and the boiler house of the Cataluna Power Station, which has a capacity of 80,000 h.p. and supplies electricity to Barcelona. The dynamos are carried at a depth of 50 ft. by six pillars of reinforced concrete, and produce no perceptible vibrations, even though each machine has a capacity of 80 h.p. The boiler room (*Fig.* 2) is very interesting, with its coal chutes and hoppers supported in mid-air in the manner shown in the illustration.

The Pier (*Fig.* 3) is also of interest because of the difficulties which are necessarily encountered when building in the open sea. The foundations of the central pier occupy an area of about 66,000 sq. ft., and are sunk in the sand.

Factories.—Among the numerous factories built by this firm may be mentioned a flour mill, including underground granaries for wheat, engineering

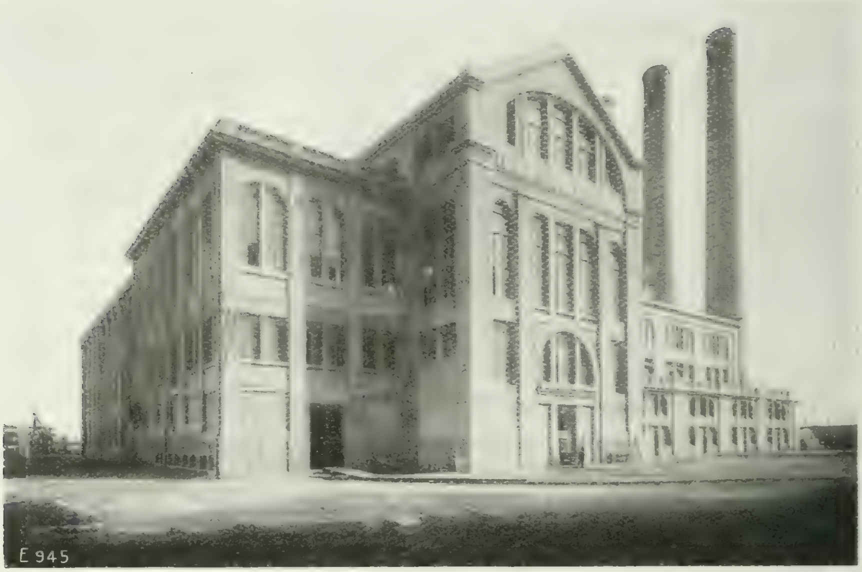


FIG. 1. A GENERATING STATION AT CATALUNA.

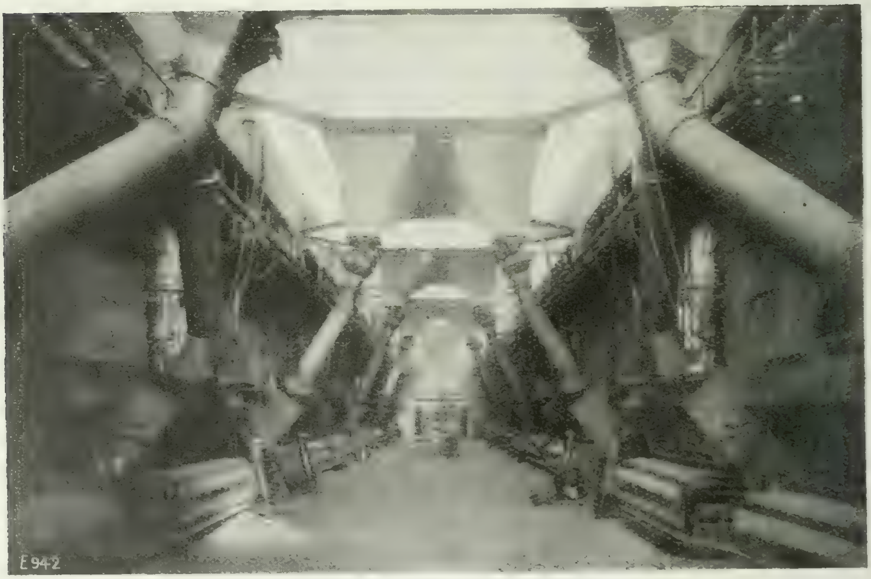


FIG. 2. A BOILER HOUSE AT CATALUNA.

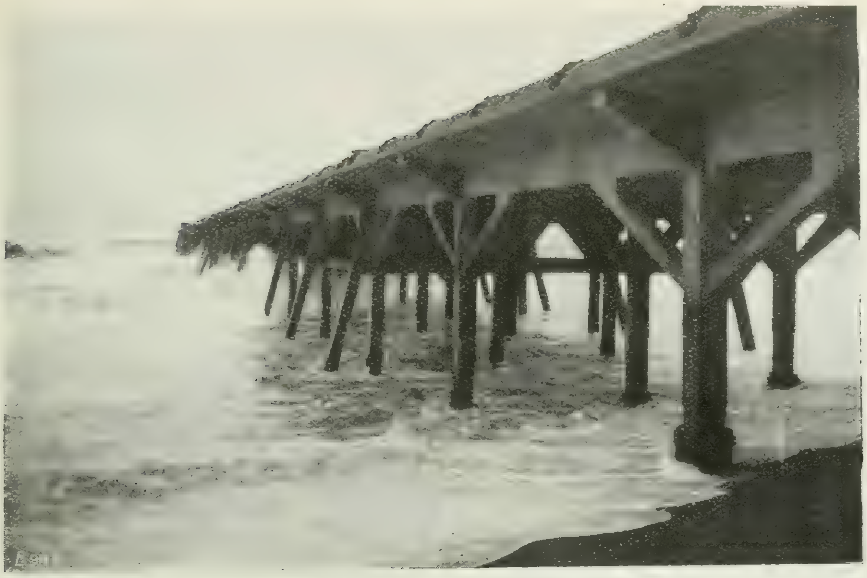


Fig. 3. Reinforced Concrete Pier, Cataluna.

Fig. 4. A Motor Car and Aeroplane Factory

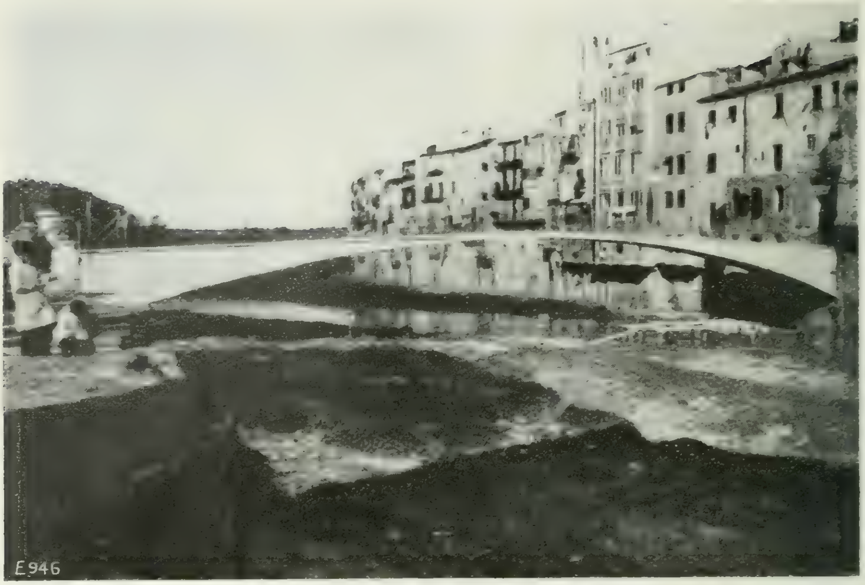


FIG. 5. REINFORCED CONCRETE BRIDGE, PUERITA.

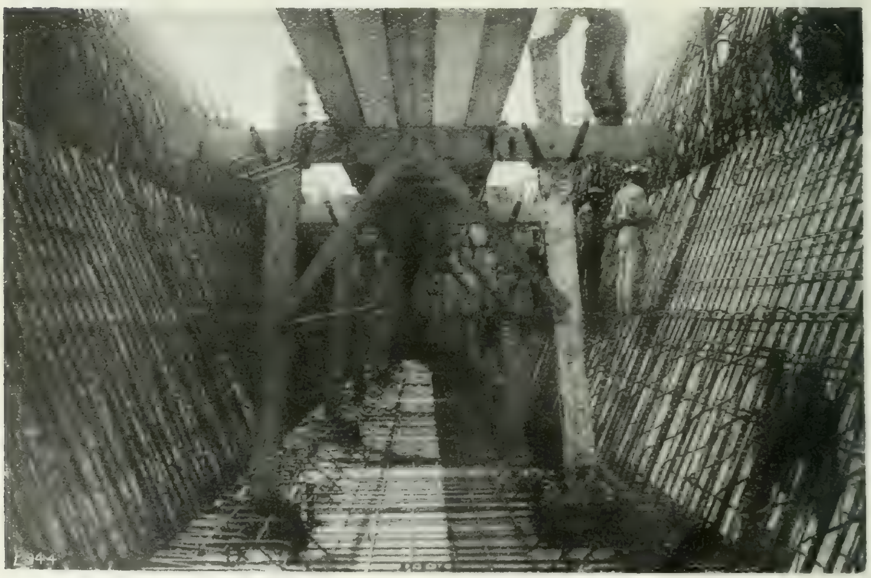


FIG. 6. REINFORCEMENT OF A SILO.

workshops, an oil-engine works, a cabinet and furniture factory, a factory for motor cars and aeroplanes (*Fig.* 4), which covers an area of about 22,000 sq. ft., and a cement works.

Warehouses and *Garages* for motor cars have been built in several localities.

The *Public Buildings* built by the firm include a large bank at Barcelona in modern Gothic style; the Palace Hotel, Madrid, in the French Classic style; and the magnificent Hotel Ritz, now in course of construction at Barcelona.

Bridges.—Among the various bridges which have been built are those with straight pillars, those with continuous pillars, one with triangular pillars, and one with an 160-ft. span and only 6½ in. thick at the centre (*Fig.* 5). At present the firm is building two other important bridges.

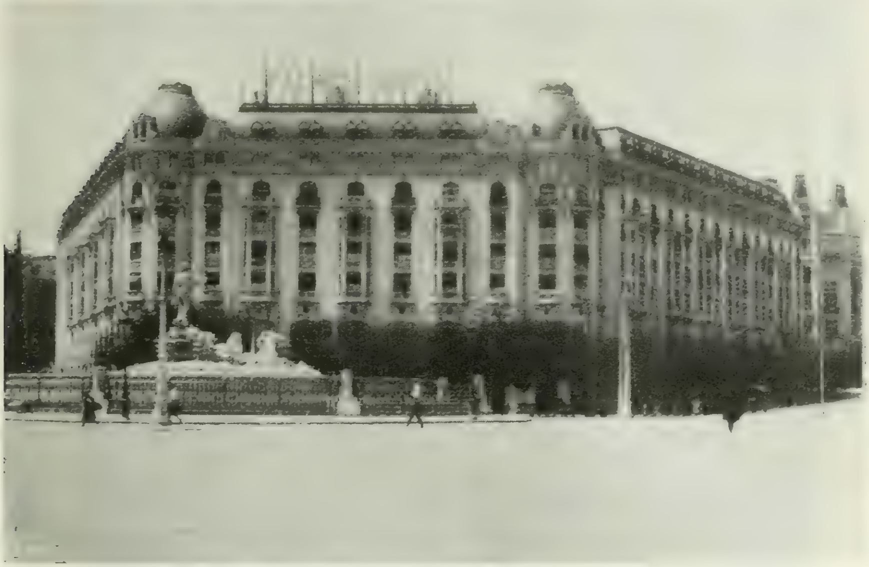


FIG. 7. AN HOTEL ERECTED IN REINFORCED CONCRETE.

Private Buildings.—Numerous blocks of houses, hotels, and chalets have also been built by the firm in various architectural styles, both modern and classical.

Miscellaneous.—Among many other structures may be mentioned water towers, posts for electric cables, canals for the water used to drive hydro-electric turbines of two large generating stations and large silos (*Fig.* 6). This firm was also the first to construct concrete vessels in Spain.

There seems to be some reason to believe that the beautiful country of Spain, with its abundant water power and richness in minerals and favourable climate, is making progress at a far greater rate than is commonly supposed, and we are pleased to be able to draw our readers' attention to this fact.

CONCRETE VESSELS IN SPAIN.

On p. 677 of our last volume we referred to a vessel being constructed by Mr. J. Capmany, the engineer in the Reinforced Concrete Department of the Sociedad Anon. Construcciones y Pavimentos, and through the courtesy of this gentleman we are now able to publish three more photographs of his work. *Fig.* 9 shows part of the shuttering used for the first concrete vessel to be

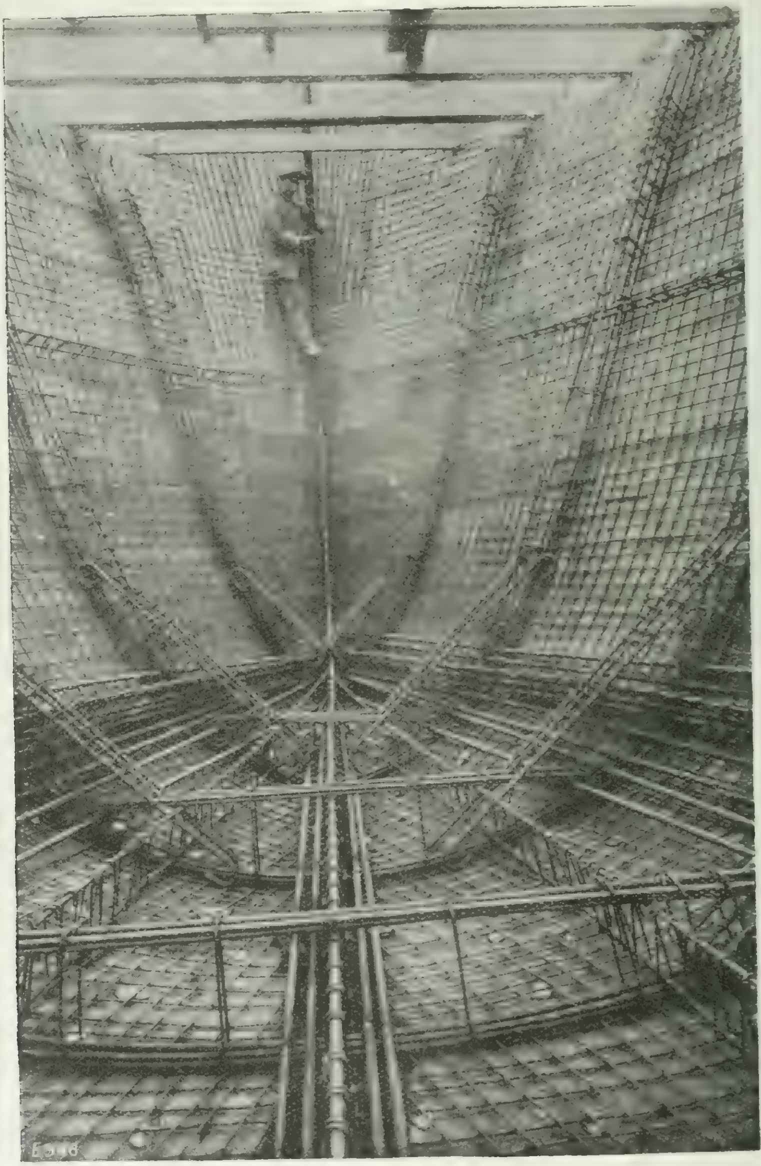


Fig. 8. Reinforcement of Stern of Vessel.

constructed in Spain; *Fig.* 8 and Frontispiece show portions of the reinforcement.

The vessel has now been completed and has a length of 113 ft., a width of 24 ft., a depth of 11 ft. 6 in., and a displacement of 450 tons.

Docks capable of accommodating forty ships each of 6,000 tons displacement are now being constructed on the Mediterranean coast, near Malgrat, and the construction of large concrete vessels is being proceeded with as rapidly as possible.

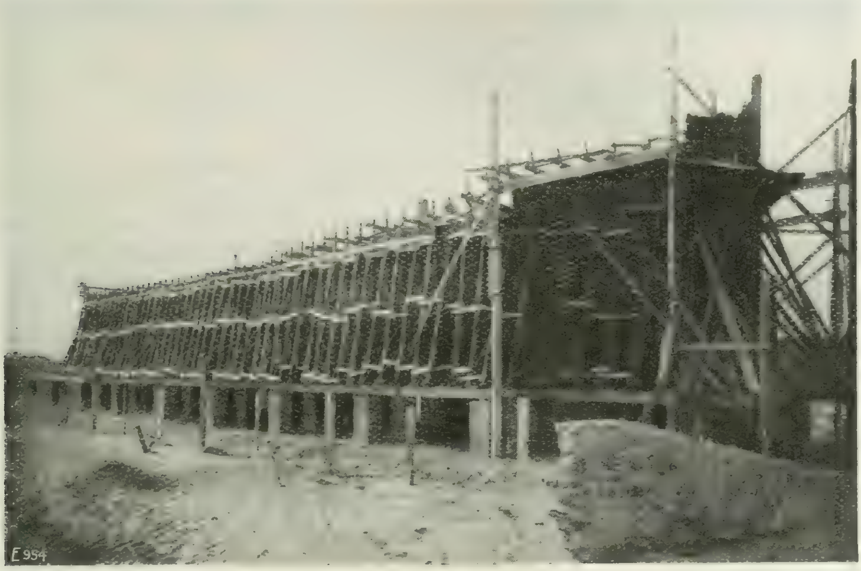


FIG. 9. SHUTTERING OF CONCRETE VESSEL.

MEMORANDUM.

The Concrete Ship "Faith."—In our March issue we gave some details of the large concrete vessel "Faith," which has been constructed in America, and in our April number we reproduced the cablegram announcing that this ship had been successfully launched. We learn that the launching of the "Faith" has been so successful that a large number of other vessels of this type are now under construction. Some illustrations of the completed vessel will appear in our next issue.

The first large sea-going reinforced concrete vessel built in the United Kingdom has recently been completed. The vessel is 150 ft. in length and some 25 ft. broad, has a displacement of 900 tons and a deadweight carrying capacity of about 400 tons. It is divided by four watertight bulkheads which are practically stone walls, three compartments being used for carrying. The forward compartment is used for stores, holds, and chain lockers, while the aft compartment contains the crew's quarters.

Messrs. J. and W. Stewart, of 42, Albemarle Street, W.1, the well-known concrete specialists, are responsible for this vessel.

In our next issue we hope to be able to give some illustrations of this ship.

Concrete Shipbuilding in America.—The United States Congress is to be asked for $50,000,000 for the development of concrete shipbuilding. It is intended to establish immediately five Government yards on various parts of the coast.

REINFORCED CONCRETE REGULATIONS, SYDNEY.
N.S.W.

By

CHARLES F. MARSH.

Reinforced Concrete Regulations have recently been issued for the city of Sydney, N. S. W., and it is proposed in a series of two or three articles to review these regulations, comparing them with the L.C.C. regulations on this subject. Mr. Marsh, in the present article, deals primarily with the parts which are similar to our own L.C.C. regulations.—ED.

These regulations appear generally to be based upon American practice, and while in some respects they follow almost the identical wording of those used by the London County Council, they depart from them almost entirely where dealing with the design of the various members. The various equations for the design of members are set out in an appendix and not in the body of the regulations, as has been done by the L.C.C.

It is proposed in the first article to deal specially with the paragraphs, etc., which are the same or similar to the regulations of the L.C.C.

Part I. (General), including regulations 1 to 6 inclusive, are identical in wording to the L.C.C. regulations, excepting that regulation 6 does not require the deposit of a copy of the calculations of the loads and stresses to be provided for, but only calls for a copy of the statement of the loads to be provided for.

An addition also appears to regulation 6 to the effect that permission to erect any reinforced concrete structure does not in any manner imply the acceptance of the work or responsibility for the actual construction, and that the sufficiency of any design shall be determined in accordance with the method set out in the regulations and appendix.

Part II. (Data to be used for the purpose of the regulations) covers the remainder of the regulations affecting reinforced concrete, with the exception of foundations, which are covered by Part III.

Regulations 7 to 35 are in almost identical wording to regulations 7 to 33 of the L.C.C. regulations.

Regulation 11 is one which is not included in the L.C.C. regulations, and is to the effect that the superimposed load for which the floor is designed shall be conspicuously displayed on each floor of commercial buildings.

Regulation 23 provides that a static pressure of 30 lb. per sq. in. may be allowed on external walls, and is the same as regulation 130 of the L.C.C.; but there appears to be some confusion as to this provision, since under regulation 137 a static pressure of only 20 lb. per sq. ft. is permitted on external walls.

Regulation 7 provides, in addition to the wording of regulation 7 of the L.C.C., "Partitions not more than 4 in. thick are to be calculated as follows:-

"The type of partition to be used having been decided, its weight per lineal foot —taking the height from floor to ceiling—being then determined, it is to be uniformly distributed over the floor area at the rate of one-seventh of the weight per lineal foot of partition to every sq. ft. of floor slab. Partitions over 4 in. thick are to be specially provided for."

In *Regulation* 10 the floor loads permitted vary in many instances, those in the Sydney regulations being less than in the regulations of the L.C.C. The comparative values are given in the following table :—

	Equivalent Dead Load in Lb. per Sq. Ft.	
For a Floor intended to be used for the purpose of—	Sydney.	L.C.C.
Domestic buildings not hereinafter specified ...	50	70
Other similar purposes ...		
Asylum wards ...		
Common lodging-house bedrooms ...		
Hospital wards ...	50	84
Hotel bedrooms ...		
Workhouse wards ...		
Other similar purposes ...		
Counting houses ...	100	100
Offices ...	60	100
Other similar purposes ...		
Art galleries ...		
Churches ...		
Chapels ...		
Class-rooms in school buildings, not being dwelling-houses so used		
Lecture rooms ...		
Meeting rooms ...		
Music halls ...	100	112
Public assembly ...		
Public concert rooms ...		
Public library reading rooms ...		
Retail shops ...		
Theatres ...		
Workshops ...		
Other similar purposes ...		
Ball rooms ...		
Drill rooms ...	150	150
Other similar purposes ...		
Similar floors subject to vibration ...		
Book stores at libraries ...		
Museums ...		
For every floor in a building of the warehouse class, except such floors as are intended to be used for any of the purposes aforesaid not less than ...	200	224
Flat roofs ...	120	—
Hardware, machinery and paper stores, and printeries ...	300	—

Regulation 13 varies from regulation 12 of the L.C.C. in that the weight of snow is omitted, and the superimposed loading is to be estimated at 40 lb. per sq. ft. on the vertical plane from the ridge to the eaves, instead of at 28 lb. per sq. ft. of sloping surface, normal to such sloping surface, as defined in the L.C.C. regulations.

Forty pounds per sq. ft. normal to the vertical plane would be equivalent to 13·7 lb. per sq. ft. normal to a plane at an angle of 20° to the horizontal, and adding a vertical loading for snow of 5 lb. per sq. ft. would increase the 13·7 lb. per sq. ft. to 18·4 lb. per sq. ft.; 40 lb. per sq. ft. normal to the vertical plane, together with 5 lb. per sq. ft. normal to the horizontal plane, would be equivalent to 28 lb. per sq. ft. normal to a plane at an angle of 37° to the horizontal.

It is hardly necessary to point out that the Sydney regulation is a more reasonable one than that of the London County Council, since, although the wind does not necessarily always act in a horizontal direction, it certainly does not always act in a direction normal to the slope of a roof, while the snow load must always act vertically.

Regulation 14 is the same as regulation 12 of the L.C.C., making a loading of 56 lb. per super ft. obligatory on any roof sloping at a lesser angle than 20° to the horizontal. The adoption of this loading for a horizontal roof, or one with a fall necessary for the purposes of drainage, is justifiable, since such a roof may at any time be subject to a loading due to a congregation of people, and it is very seldom if ever that a roof is designed with any slope between a slight fall for drainage purposes and an angle of 20° to the horizontal.

Regulation 19, like regulation 18 of the L.C.C., does not state to what plane the angle of dispersion of 45° for a concentrated load may extend; but it is believed that the intention is that it may extend to the plane of the main tensile reinforcements.

Regulation 20 is the same as regulation 19 of the L.C.C., and provides for a rate of reduction of 5 per cent. of the superimposed loading for each floor from the second story from the top of a building, until the total reduction amounts to 50 per cent., when assessing the loading on columns and foundations. It is a moot point as to whether this rate of reduction might not be increased to 10 per cent., the total reduction remaining 50 per cent.

Regulation 29 is the same as the L.C.C. regulation 27, and provides that the ratio of the span of a beam to its effective depth shall not exceed the lesser of the two following ratios:—

$$20 \times \frac{\text{permissible tensile stress on the reinforcement}}{\text{actual maximum tensile stress on the reinforcement}}$$

or

$$20 \times \frac{\text{permissible compressive stress on the concrete}}{\text{actual maximum compressive stress on the concrete}}.$$

And *Regulation* 30 is the same as regulation 28 of the L.C.C., and provides that the length of a cantilever shall not exceed five times the effective depth at the bearing. It will be noticed that in the case of a beam the ratio of the length to the span is not to exceed 20 when it is loaded in such a manner as to stress the reinforcement or the concrete to their maximum permissible resistance, but that the ratio may be increased as the loading is reduced.

In the case of a cantilever no increase can be made in the length for a lighter loading than that which will cause the maximum permissible resistances, although there can be no reason for more latitude for the one case than for the other.

Regulation 33 is the same as regulation 31 of the L.C.C., and provides that the effective span of a continuous beam shall be taken as the clear span, plus the effective depth, or the span between the centres of the necessary bearing surfaces, whichever may be the lesser.

This regulation has an important bearing on the design of continuous beams. It permits a considerable reduction of the bending moment over wide supports of continuous beams or slabs, since it is permissible to neglect the peak of the bending moment diagram as constructed for a continuous beam or slab from centre to centre of supports.

The Sydney regulations have omitted an important proviso upon which the granting of the relief given under regulation 33 depends. This proviso is enforced under regulation 38 of the L.C.C., which provides that the maximum area of steel required to take the negative bending moment at any support shall be carried without reduction across the centre of that support.

Regulations 86, 87, and 88 are the same as regulations 39, 40, and 41 of the L.C.C.

The regulations as to bending moments vary in many respects from the L.C.C. regulations. Those for freely supported beams, beams with fixed ends, and cantilevers, are identical; while those for continuous beams are generally the same as the approximate values given in the L.C.C. regulations, excepting that the constraint of the ends is provided for by allowing in ordinary cases $\frac{wl^2}{16}$, and in the case of small beams running into columns $\frac{wl^2}{12}$.

A parabolic loading is allowed on beams supporting slabs, and formulæ are given for the bending moments and shears for this form of loading. The regulations with respect to working stresses follow the recommendations of the final report of the special committee on concrete and reinforced concrete of the American Society of Civil Engineers, and are entirely different from the L.C.C. regulations. Eccentric loading on columns and combined stresses are provided for under regulation 69 in a similar manner to regulations 44 and 45 of the L.C.C. Connections in or between the several members of a structure are not provided for.

Regulation 91 provides that where the main reinforcing bars are bent up to resist shearing stresses the *maximum* radius of the bend shall be fifteen diameters, except at hooks—it would appear that in this case "the maximum radius" should be "the minimum radius." It would have been advisable to have included a regulation dealing with this requirement in the L.C.C. regulations.

Regulation 92 provides that all hooked ends at the end of plain reinforcing bars, either bent up, straight, or stirrups, shall be bent to a curvature having an internal radius of two and a half times the diameter of the bar and a straight termination of a length equal to five times the diameter of the bar, except where approved deformed bars are used, when a 3-in. rectangular bend may be used.

This regulation is similar to regulations 48 (a) (b) and (c) of the L.C.C. regulations, which provide that hooked ends shall have an internal radius of twice the diameter of the bar and a straight termination of a length equal to four times the diameter of the bar, and that if the anchorage is secured by other means than a hook it shall be bent to a right angle, the width across the anchorage being at least three times the normal diameter of the bar.

The regulations with respect to the design of beams and columns follow the recommendations of the final report of the special committee on concrete and reinforced concrete of the American Society of Civil Engineers, the provision as to joints in the longitudinal reinforcement to columns (regulation 70) being the same as regulations 110 and 111 of the L.C.C.

The regulations with regard to walls are unlike the L.C.C. regulations. They commence with regulation 133, giving definitions of the various types of wall.

Regulation 134 provides that the lateral and compressive stresses shall not exceed the safe stresses allowed for other members under similar conditions.

Regulation 136 provides as to openings, and differs from regulation 131 of the L.C.C. in that it allows of openings not exceeding three-quarters the whole area of the wall in the external wall of any storey above the ground storey; whereas regulation 131 of the L.C.C. regulations allows openings of only two-thirds the whole area of the wall, with an aggregate width not exceeding three-quarters the whole length of the wall.

Regulation 137 provides that external walls must be designed to resist safely a horizontal pressure equivalent to a static pressure of not less than 20 lb. per sq. ft. on either side; whereas regulation 130 of the L.C.C. permits of a static pressure of at least 30 lb. per sq. ft.

Regulation 142 provides that bearing piers between openings shall be capable of bearing the entire load, and shall be calculated as columns. The L.C.C. regulations do not contain any such proviso.

Regulation 143 provides that all mullions under 14 in. wide or more than 6 ft. high bearing a load shall have a steel core. There is no provision such as this in the L.C.C. regulations.

Regulation 148 provides that reinforced concrete curtain walls shall be at least 6 in. thick, but where the area between adjacent vertical and horizontal framework exceeds 300 sq. ft. and is less than 400 sq. ft. the wall shall be not less than 8 in.

thick; and where the area as above described exceeds 400 sq. ft. the wall shall not be less than 12 in. thick.

Regulation 126 of the L.C.C. allows curtain walls between reinforced concrete piers, beams, arches, etc., to be 4 in. thick, provided that such walls be designed and constructed to resist any loads and pressures they may have to carry; while regulation 127 of the L.C.C. provides that where any wall or part of a wall is intended to support vertical loads or lateral pressures it shall be of such thickness as may be necessary to keep the stresses within the prescribed limits.

It will be seen that the Sydney regulations with respect to curtain walls vary considerably from those of the L.C.C.

Regulation 149 provides that on reinforced concrete walls the area of steel reinforcement shall be $\frac{1}{2}$ per cent. of the area of concrete, one-half being placed vertically and one-half horizontally; and regulation 150 provides that if the reinforcement is spaced more than 14 in. apart additional reinforcement shall be wired at intersections and that the reinforcements shall be rigidly connected at columns and girders to the reinforced concrete frame.

The L.C.C. regulations do not contain any provisions similar to the above, excepting that in the L.C.C. regulation 129 it is provided that all walls and facing materials shall be securely connected to pillars, beams, floors, and other contiguous parts.

Regulation 152, with respect to hollow blocks, is identical in every respect to regulation 128 (a) (b) (c) (d) and (e), but there is, of course, no proviso such as contained in the last paragraph of regulation 128 of the L.C.C.

Regulation 170 provides that the pressure on concrete in foundations must not exceed 20 per cent. of the compressive strength of the standard concrete cylinder (8 in. in diameter and 16 in. long) at 28 days; whereas regulation 137 of the L.C.C. provides that the pressure shall not exceed 12 tons per sq. ft.

The bearing pressures of natural ground are dealt with under regulation 171 of the Sydney bylaws and regulation 136 of the L.C.C.; the respective values are given in the following table in tons per sq. ft.:—

Nature of Ground.	Sydney.	L.C.C.
Sound sandstone rock	20	—
Sound shale rock	8	—
Natural compact gravel	6	4
Hard clay or ordinary compact shale	4	—
Confined clay or confined sand or mixed clay and sand	2	—
Soft clay or wet or loose sand	1	1
London blue clay or chalk	—	4
Ordinary clay or confined sand	—	2

Regulations 94 and 95 provide for the thickness of protecting coating, which is to be measured from the outer surface of the concrete to the outer surface of the reinforcement, and be not less than 2 in. for columns, $1\frac{1}{2}$ in. for beams, and 1 in. for slabs. It is also provided that the protecting coating shall not be included in calculations for strength.

No exceptions are made to the latter proviso, but it is probable that the covering to compression bars would be allowed to be included in the concrete resisting compressive stresses in beams and slabs.

Regulations 138 to 143 of the L.C.C. provide for protective coverings. Under these regulations the covering beyond anchored ends bent at right angles is not to be less than 2 in., or than twice the normal diameter of the bar.

The cover for bars in columns is not to be less than $1\frac{1}{2}$ in., or than the diameter of the bar.

The cover for bars in beams is not to be less than 1 in., or than the diameter of the bar.

The cover for bars in slabs is not to be less than $\frac{1}{2}$ in., or than the diameter of the bar.

The cover for bars in other members is not to be less than 1 in., or than the diameter of the bar.

L.C.C. regulations 99, 113. and 121 govern the area of concrete in columns or struts which is to be allowed when calculating the stresses, and provide that the protective covering is not to be included in this area.

The Sydney regulations with respect to materials differ widely from those of the L.C.C., and the two cannot be compared.

Regulations 115 to 120 deal with formwork or centering.

Regulations 115, 116, 117, 118, and 119 of the Sydney regulations are the same as the L.C.C. regulations 173, 174, 175, 176, and 177 respectively, excepting that regulation 118 of the Sydney bylaws varies from 176 of the L.C.C. in that it provides that all struts shall be wedged with folding wedges, that the centering for walls may be removed as soon as it can be stripped without injury to the concrete, but in not less than 24 hours after pouring of the concrete, and that the centering for floor slab soffits and beams and column sides may be removed in not less than seven days after concreting, or not less than one day per ft. span of the slabs, whichever is greater; that the centering for beam soffits shall remain in position not less than 28 days after concreting. It also provides that all centering shall be carefully hosed off and sawdust and shavings removed immediately prior to concreting; and that all column moulds shall be constructed with the bottom board on one side removable, so that it may be seen that the column box is cleaned out before any concrete is placed on the column.

Regulation 120 provides that the forms shall be of sound pine or other suitable timber, framed in such a manner as to prevent leakage.

In the Sydney regulations the methods of calculation are placed in an appendix, and not in the body of the regulations, as is the case in the L.C.C. bylaws.

Calculations are included for shear, bond, and web reinforcement, doubly reinforced rectangular and tee beams, and for columns under direct compression and bending combined, none of which are specially provided for under the L.C.C. regulations.

The breadth of the flange allowed when calculating the resistance of T beams is to be not more than one-fourth the effective span, and the width of overhang on either side of the web is not to exceed six times the thickness of the slab. These provisions follow the recommendations of the special committee on concrete and reinforced concrete of the American Society of Civil Engineers.

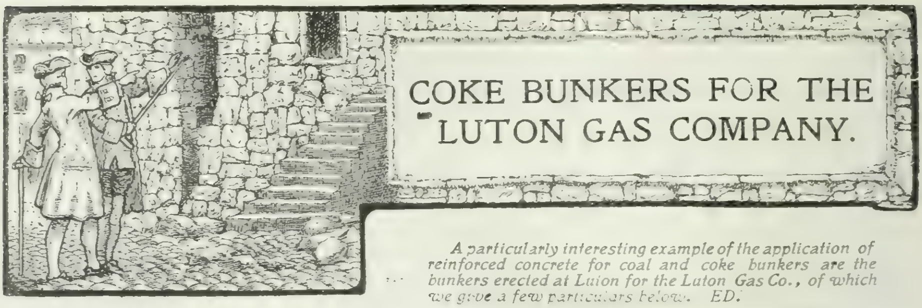
The L.C.C. regulation 82 allows not more than one-fourth of the effective span, the distance between the centres of the ribs, or twelve times the thickness of the slab, whichever is least.

L.C.C. regulation 83 provides for the flange width of ell beams, which are not provided for under the Sydney bylaws.

L.C.C. regulation 84 provides that the minimum breadth of the rib shall not be less than one-third the depth of the rib below the slab. The Sydney bylaws make no ruling on this point, and such a provision is really unnecessary, since the proper spacing of the longitudinal bars and the provision against diagonal tension will ensure a proper width for the rib.

L.C.C. regulation 86 provides that the reinforcement of the slab transverse to the beam must cross the full breadth of the portion of the slab forming the flange. The Sydney regulations provide for this by stating that when the principal slab reinforcement is parallel to the beam transverse reinforcement should be used, extending over the beam and well into the slab.

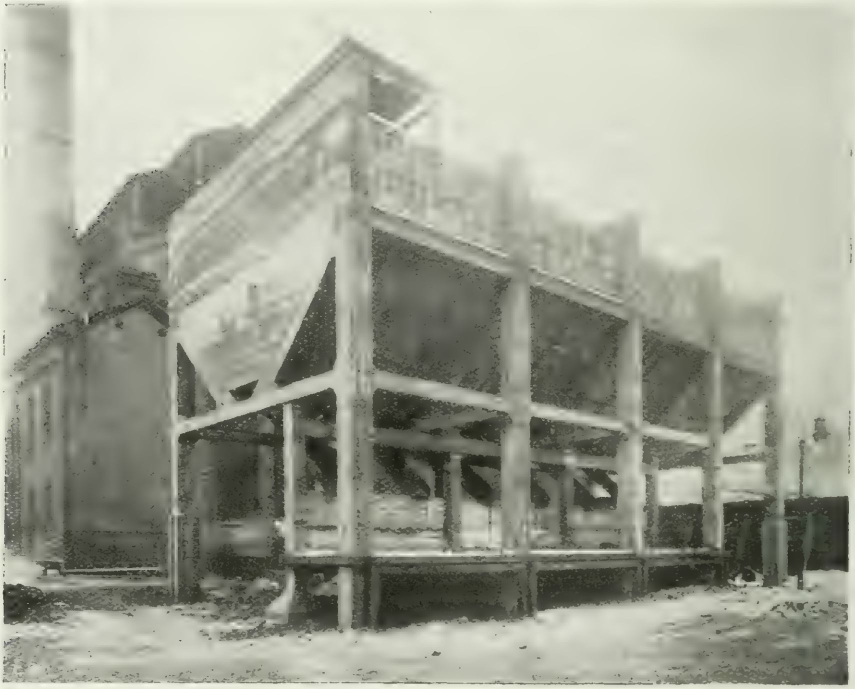
It is believed that all points of similarity between the Sydney regulations and those of the L.C.C. have been dealt with in this article. It is proposed to give a further article dealing with the regulations with respect to materials and design.



COKE BUNKERS FOR THE LUTON GAS COMPANY.

A particularly interesting example of the application of reinforced concrete for coal and coke bunkers are the bunkers erected at Luton for the Luton Gas Co., of which we give a few particulars below. ED.

THE accompanying illustration shows the coke bunkers, calculated to contain approximately 100 tons of coke, recently erected for the Luton Gas Company on the Coignet system, in accordance with the general plans and requirements of Mr. W. Phillips, Jun., the engineer and assistant general manager to the gas company. This work was urgently required in order to rapidly dispose of the coke and also to economise the labour in handling same.



COAL AND COKE BUNKERS FOR THE LUTON GAS COMPANY.

The bunkers are fitted with a specially designed screen, with sliding doors and levers to facilitate the sacking operation, which is carried out on a special platform at a convenient level to enable the sacks to be easily placed into the carts. One of the bays is left open and has no platform in order to enable carts to be filled directly from the hoppers. A gangway has been provided running on the top of the bunkers to enable trucks to be discharged from this higher level. The trucks are first wheeled from the retort house into an hydraulic lift, which takes them up to the level of the top of the bunkers. They are thence pushed along a gangway which leads to the top of the bunkers. Removable handrails have been provided for to prevent the men from accidentally falling into the bunkers.

The general dimensions of the structure are as follows :—

	Ft.	In.
Length, approximately	48	6
Width, approximately	22	0
Total height from the underside of the reinforced concrete footings	30	0

The panels of the hoppers are 7 in. thick. The panels of the walls 4 in. thick. Round steel bars were used exclusively for the whole of the reinforcement, and the concrete was made with a mixture of 1, 2, 4.

The bunkers were tested with a full load of coke about two months after the completion of the work with satisfactory results.

The detailed drawings and the supervision of the work were carried out by Messrs. Edmond Coignet, Ltd., the well-known reinforced concrete specialists of 20 Victoria Street, Westminster, and the work was executed by Mr. T. Watson, of London, licensee of the above system.

MEMORANDA.

Concrete Tanks for Photographic Solutions.—In a recent issue of *Concrete*, U.S.A., Mr. Cloyd M. Chapman discusses the possibility of using concrete tanks for photographic solutions, and states that such tanks are entirely practical, serviceable and satisfactory. They may be constructed in the same way as tanks of similar size for water. They may be thin in section, reinforced with wire mesh or expanded metal, made smooth on the inside and outside with mortar, and kept moist until thoroughly hardened. They should then be coated both inside and outside with two or more coats of a bituminous base, water and acid proof paint. Concrete without such a coating will not withstand the action of the acids, alkalies and salts used in photographic solutions. But with a coating as above indicated concrete tanks or trays will give complete satisfaction in the photographic laboratory.

According to information received by the editors of the journal from which we quote: "The Eastman Kodak Co., of Rochester, report the satisfactory use of concrete tanks for photographic solutions. They made their tanks of a rich mortar containing waterproofing on ½-in. galvanized wire mesh; they were finished smooth inside, lined with waterproof paper, and then coated with asphalt paint." The experience of other firms is also given.

Reinforced Concrete for a Church in Derbyshire.—The question of a new parish church for Swadlincote was recently discussed. A statement of the condition of the present structure showed that it would be undesirable to expend a large sum on renovations. The opinion was expressed that it would be wiser to erect a reinforced concrete church outside the walls of the present edifice. Although the proposal will not be acted upon at the moment, the scheme will probably be adopted eventually.

SOME RECENT VIEWS ON CONCRETE SHIPBUILDING

ON THE DESIGN AND CONSTRUCTION OF SELF-PROPELLED REINFORCED CONCRETE SEA-GOING CARGO STEAMERS, NOW BUILDING IN GREAT BRITAIN.

By T. G. OWENS THURSTON.

In continuation of the Papers read at the Institution of Naval Architects on Concrete Shipbuilding we now reproduce the interesting contribution made by Mr. T. G. Owens Thurston. Several valuable plates illustrating the vessels under construction at Barrow accompanied the Paper. These, owing to lack of space, we are unable to reproduce.—ED.

FOR years past one has heard of the construction of small vessels or barges of reinforced concrete, but these were never of sufficient size or importance to warrant closer investigation, and the whole subject appeared to be one that could safely be ignored so far as ocean-going ships were concerned.

The enormous losses of cargo-carrying ships during the war, coupled with the great scarcity of steel for shipbuilding on account of its diversion to other uses, have made shipbuilders endeavour to find some other material to replace steel for ship construction, even if only as a temporary measure; in this particular direction shipowners have perhaps been really more progressive in their ideas than the shipbuilders. It was largely owing to shipowning friends of mine, who recognised the disastrous effect which the immense losses of mercantile tonnage would eventually have on the country, that steps were taken which led to the inception of the design and construction of the ships forming the subject of this paper. Without knowing anything as to the merits of reinforced concrete for shipbuilding purposes, they considered that if small craft had already been built with such material it was worth a trial, under present conditions, in larger ones, and after much consideration and investigation of the work previously done in this direction the author finally agreed with them.

The possibility of building wooden ships to make up for the scarcity of steel ships had been carefully considered, but it was found that, although the timber supplies in certain countries were adequate for the purpose, a long time must elapse before green timber would be sufficiently seasoned to allow of its efficient use in ships' hulls, although in many cases such timber has been used, and has proved more or less satisfactory for a limited time. In addition to this the problem of skilled labour would have been accentuated rather than relieved, as it was a practical impossibility to get a sufficient number of men skilled in wooden shipbuilding to allow of construction except on a very moderate scale. These and other considerations led us to abandon the idea of wooden shipbuilding as an efficient substitute under the present urgent circumstances in favour of reinforced concrete, the latter being a material which if successful would at once allow a large addition to be made to the present output of cargo-carrying tonnage. Moreover, the system of construction calls for a minimum amount of steel and a minimum amount of skilled labour. Such construction also reduces capital expenditure on yard plant, as it is much less costly than ordinary shipyard plant and requires less skilled attention. Another point in favour of reinforced concrete construction is that, compared with ordinary shipyard labour, there is not so great a variety of trades involved. For example, the same men who at a later date are employed on casting the hull are in the initial stages utilised in casting and laying concrete blocks and in making reinforced concrete piles for the building berths and other necessary preliminary work, for which this material can be used extensively instead of timber or steel, both of which require skilled labour of different trades.

Although the suitability of reinforced concrete under present abnormal conditions and on economical considerations was apparent, its acceptability for ship construction had to be investigated from the naval architect's point of view. With this object in view, we decided to design a sea-going cargo vessel of reasonably large dimensions, to assure ourselves that such a vessel, constructed of reinforced concrete, would satisfy conditions of strength, seaworthiness, deadweight capacity, etc. The difficulties in the preparation of the design proved much greater than was anticipated, for whilst we, as shipbuilders, could prepare and supply the particulars and drawings of the vessel and approximate to the maximum stresses coming on the various members, we had no practical experience of the construction of the reinforced concrete part of the hull, so that it became necessary to work in conjunction with a reliable firm of reinforced concrete engineers, who would carry out this part of the design, basing it on work actually done. This association of shipbuilders and reinforced concrete engineers has proved mutually satisfactory and advantageous, and each party found that it had something to learn from the other with respect to shipbuilding of this type.

It was eventually decided that a self-propelled cargo vessel of about 1,150 tons deadweight was as large as we were justified in commencing as a first venture. It was agreed that the vessel should comply with all the requirements obtaining for steel vessels, and the general scheme was based upon that of a similar ship constructed of steel. The dimensions, for reasons which occurred in preparing the design, differed from those of a steel ship of the same deadweight carrying capacity, especially in length. The dimensions and other particulars finally decided upon were as follows :—

Length between perpendiculars...	205 ft.
Breadth moulded...	32 ft.
Depth moulded	19 ft. 6 in.
Draught when loaded	15 ft. 6 in.
I.H.P. (about)	400
Speed (about)	$7\frac{3}{4}$ knots.

The various arrangement drawings were prepared and scantlings arranged in accordance with Lloyd's Rules for Steel Ships. Using these scantlings, a list was made up of the calculated section moduli of the various members. Upon these particulars the engineers prepared constructional sections, on the Hennebique principle of " equivalent strength," which were adopted as a basis for calculation of weights, etc.

The design was then carefully reconsidered and calculations made as far as possible for the stresses which the vessel would be subjected to, both longitudinally and transversely, under all reasonable conditions of construction, launching, and service.

One of the first things observed in the case of the reinforced concrete hull was that the centre of gravity of the structural material worked out much lower than in the case of a steel hull, the result being a greater metacentric height than was desirable. To minimise this the original beam of 34 ft. was reduced to 32 ft., and in order to obtain the same hold capacity the depth was increased from the original 17 ft. 6 in., to 19 ft. 6 in., fortunately, from the point of view of longitudinal strength, a modification in the right direction.

Longitudinal Strength.—In calculating longitudinal stresses the vessel was first of all assumed to be in still water with the holds loaded uniformly to the full-load condition, giving a displacement of 2,350 tons. In this condition the maximum bending moment worked out at about 4,100 foot-tons. For hogging stresses the vessel was taken as being in the same load condition and on the crest of a trochoidal wave of length equal to the length B.P. of vessel, and height equal to $\frac{\text{Length}}{20}$, giving a maximum shearing force of 180 tons and a maximum bending moment of 10,000 foot-tons.

In the sagging condition the vessel was much more severely loaded, three-fifths of the cargo being placed in the middle of the hold space and one-fifth at each end respectively, resulting in a maximum shearing force of 180 tons and a maximum bending moment of 7,000 foot-tons.

In the case of launching, the maximum shearing force reached as high as 220 tons, with a maximum bending moment of 10,000 foot-tons. A generous margin was allowed over these figures, and the vessel was designed to stand the stresses corresponding to the following :—

Hogging moment ... ... $\frac{\text{Displacement} \times \text{length}}{35} = 13{,}500$ foot-tons

Sagging moment ... ... $\frac{\text{Displacement} \times \text{length}}{48} = 10{,}000$ foot-tons

Shearing force ... ... $\frac{\text{Displacement}}{9 \cdot 8} = 240$ tons

the structural material being arranged so that the tensile stress on the reinforcement, taking account of all local stresses, never exceeded 9 tons per sq. in., and the maximum compressive stress on the concrete 750 lb. per sq. in.

Transverse Strength.—In calculating transverse strength the transverse framing was analysed in order to ascertain the maximum bending moment to be resisted by the floors, frames, and beams under the various systems of loading to be met with in service.

The conditions assumed, for which calculations were made, are as follows :—

(1) Vessel, without pillars, loaded to deep draught in still water. Cargo load in hold and on deck.

(1*a*) Vessel, with two pillars fitted, one at each side of hatch opening, loaded to deep draught in still water as in condition (1).

(2) Vessel, with two pillars fitted, loaded as in (1), and situated on wave crest, with no cargo on floor girder.

(3) Vessel, with two pillars fitted, loaded and situated in wave hollow with full cargo, load centrally placed below hatches and no deck cargo.

(4) Vessel, with two pillars fitted, in light condition, in dry dock, docked on centre keel.

The calculations were investigated on the " principle of least work," taking the reinforced framing as monolithic.

In the moment as calculated there have been taken into account the stresses in the framing where only a partial support is received from the pillaring through the medium of longitudinal girders spanning between the transverse frames. The scantlings of the framing have been proportioned to the more severe conditions met with at the centre of floor girders, bilge, side frame, deck corner, and beam.

It may be observed that if the floor girder is designed to resist the bending moment in condition (2), it is also strong enough to meet the docking condition in condition (4), where the bending moment is about two-thirds that of condition (2). In condition (3) the bending moment is reversed in direction and the floor tends to deflect downwards, caused by a bending moment approximately two-thirds of that causing the upward deflection in condition (2).

To provide an estimate of the bending moment to be allowed for in the first instance, the framing was treated as a continuous girder, and the free bending moment calculated for the several spans.

These were plotted on a straight base representing the neutral axis of the framing and the theoretical fixing moment lines drawn ; at the points of junction between the floors, frames—where the amounts of the fixing moments varied—and beams, the difference in bending moment was proportioned to the expression $\frac{I}{L}$ of the member on each side of the joint.

Neutral axis above base

$$=n=\frac{B_s \cdot d_s^2+2m\,(A_c \cdot d_c+A_t \cdot d)}{2\,\{B_s \cdot d_s+m(A_c+A_t)\}}=\frac{36\times 4^2+2\times 15(4{\cdot}16\times 2{\cdot}7+3{\cdot}85\times 33{\cdot}5)}{2\,\{36\times 4+15(4{\cdot}16+3{\cdot}85)\}}=9{\cdot}1 \text{ in.}$$

Moment of inertia

$$=I=\frac{B_s \cdot n^3}{3}-\frac{B_s \cdot X^3}{3}+m \cdot A_t(d-n)^2+m \cdot A_c(n-d_c)^2=\frac{36\times 9{\cdot}1^3}{3}-\frac{36+5{\cdot}1^3}{3}+15\times 4{\cdot}16\,(9{\cdot}1-2{\cdot}7)^2=44{,}304 \text{ in.}^4$$

Frame spacing = 3 ft.

$$\text{I per foot of spacing}=\frac{44{,}304}{3}=14{,}768 \text{ in.}^4$$

$$\text{I}_s \text{ per foot of spacing}=\frac{14{,}768}{15}=985 \text{ in.}^4 \text{ for steel reinforcement.}$$

Moment of resistance for steel $=\text{M.R.S.}=\frac{I_s}{d-n}=\frac{985}{33{\cdot}5-9{\cdot}1}=40{\cdot}37$ in.^{3} With B.M. of 30 ton-ft., max. stress = 9 tons per sq. in.

Moment of resistance for concrete $=\text{M.R.C.}=\frac{I}{n}=\frac{14{,}768}{9{\cdot}1}=1{,}623$ in.^{3}

Basis for Strength Calculation.—As a basis for calculation of strength, the following were adopted as working limits for safe stresses on concrete and steel :—

CONCRETE.

Item.	Working Stress, lb. per sq. in.	Ultimate Stress, lb. per sq. in.
Compression in beams	750	4,000
Compression direct	700	4,000
Shear	70	280
Adhesion	60	240
	100	500

STEEL.

Item.	Working Stress.	Elastic Limit.	Ultimate Stress.
Tension, spiral bars	9 tons, sq. in.	23½ tons, sq. in.	30–36 tons.
Tension, plain bars	7½ ,, ,,	15 ,, ,,	27–30 ,,
Compression	7½ ,, ,,	15 ,, ,,	27–30 ,,
Shear	5½ ,, ,,	—	24 ,,

The vessels are in course of construction at Barrow-in-Furness, and the sand and aggregate found locally have proved most satisfactory for a concrete mixture suitable for shipbuilding.

The concrete adopted is formed of a rich mixture of 1 part cement, 1·2 parts sand, and 2·4 parts granite aggregate (by volume).

The cement used weighs 84 lb. per cu. ft. The sand used is of a coarse nature, having the following sieve test :—

Mesh of Sieve.	Remaining Percentage on Sieve.
100 × 100 per in.	100 per cent.
50 × 50 ,,	61 ,,
20 × 20 ,,	14 ,,

The aggregate used consists of granite chippings from ⅜ in. downwards, weighing 92·5 lb. per cu. foot.

The proportionate amounts of cement, sand, and aggregate to form 27 cu. ft. or 1 cu. yd. of concrete are :—

9 cu. ft. cement, 10·74 cu. ft. sand, 21·47 cu. ft. aggregate = 1 cu. yd.
= 757 lb. cement + 1,192 lb. sand + 1,986 lb. aggregate = 3,935 lb.
= ·34 ton cement + ·53 ton sand + ·89 ton aggregate = 1·76 tons.
Add to this ·05 ton water = 1·81 tons per cu. yd. of concrete.

For estimating purposes 1 ton of concrete contains ·57 cu. yd.=15·4 cu. ft.; or ·192 ton cement, ·300 ton sand, and ·508 ton granite.

Machine mixing of concrete is preferable to hand mixing, inasmuch as a standard and invariable mixture may be obtained, due to the use of automatic devices for the measurement of the various ingredients as well as of measurement of the time of mixing.

Particulars and Description of Hull.—The following tables give particulars of three midship sections respectively for the reinforced concrete, a steel and a wooden ship, each designed for a deadweight carrying capacity of 1,150 tons :—

	Reinforced Concrete.	Steel.	Wood.
Length	205 ft. 0 in.	188 ft. 0 in.	205 ft. 0 in.
Breadth	32 ,, 0 ,,	30 ,, 3 ,,	36 ,, 0 ,,
Depth	10 ,, 6 ,,	17 ,, 3 ,,	18 ,, 9 ,,
Draught	15 ,, 6 ,,	14 ,, 6 ,,	16 ,, 6 ,, *
Deadweight	1,150 tons	1,150 tons	1,150 tons
Displacement (load)	2,350 ,,	1,800 ,,	2,400 ,,
I.H.P. (about)	400	400	400

Weights.

	Reinforced Concrete.	Steel.	Wood.
Steel in hull †	100 tons	445 tons	140 tons
Remainder of hull	860 ,,	80 ,,	960 ,,
Machinery and boilers	80 ,,	80 ,,	80 ,,
Outfit ‡	70 ,,	15 ,,	70 ,,
Deadweight	1,150 ,,	1,150 ,,	1,150 ,,
Load displacement	2,350 tons	1,800 tons	2,400 tons

* Includes 12 in. wood keel.
† Includes hull castings and forgings.
‡ Includes anchors, cables, boats, auxiliary machinery, etc.

It will be noticed that the weight of steel in the reinforced concrete ship is about 42½ per cent. of that in the steel ship. This is not by any means such a large reduction as some writers on reinforced concrete ship construction have anticipated, nor is it probably the minimum quantity which we could have adopted had we been prepared to incur a certain amount of risk in structural strength. In view, however, of this being our first venture in a new method of construction, we did not feel justified in reducing the strength until we had ascertained from experience how a ship constructed on this principle would act under ordinary conditions of service. One reason was that, should the vessel prove weak, it would be a matter of the utmost difficulty to introduce additional stiffening and strength. A second and even more potent reason was that we were not justified in risking the safety of the ship or the lives of the men who might navigate her, for the purpose of endeavouring in the first ship to reduce the quantity of steel that might be used to the minimum. Actual service will perhaps give an indication where weight may be saved, either in the steel or concrete of the hull; and that such saving will ultimately be effected, even with identical methods of construction, we confidently anticipate It must not be overlooked that the saving of steel effected, especially under present conditions, is of the greatest importance. If we take, say, 200 vessels similar to the one under discussion, we should have an additional carrying capacity of 230,000 tons added to our mercantile fleet, whilst there would be a total saving of 51,000 tons of steel as compared with a similar number of steel ships of equal carrying capacity. Moreover, this steel is worked in the form of reinforcement rods and is not dependent upon the plate rolling mills for its production. This is the more important, as at the present moment it is largely the limited output of the rolling mills which adds to the difficulty of procuring an adequate amount of ship building steel.

We came to the conclusion that the most economical as well as the most efficient rod for ship construction was that known as the spiral bond bar. This is an ordinary mild steel bar, which subsequent to being rolled is stressed by being twisted in such a manner that the elastic limit is raised about 35 per cent., the twist in the bar giving it at the same time a continuous mechanical bond with the concrete in which it is embedded. With this high elastic limit smaller sections may be employed than would be possible with an ordinary mild steel bar, which means a reduction in weight of steel used. As the continuous mechanical bond justifies shorter overlapping of bars at junctions, the weight of steel is again reduced. A further advantage of the special twisting treatment lies in the fact that steel of very low tensile strength may be thus treated, and so release for other important work the higher quality steel.

The following is a table of actual tests of a spiral bond bar ($1\frac{3}{8}$ in. diameter) before and after twisting :—

Original Size. Diameter.	Area.	Contraction of Area. Diam.	Area.	Per Cent.	Elongation in 8 in. Inches.	Per Cent.	Ultimate Stress. Actual Tons.	Tons per sq. in.	Elastic Limit. Actual Tons.	Tons per sq. in.
Before twisting, 1·375 in.	1·39	·88	·568	59·2	10·40	30·0	37·4	26·9	24·5	17·62
After twisting, 1·375 in.	1·39	·89	·581	58·2	9·68	21·0	41·3	29·7	33·2	23·86

See stress strain diagram, Fig. 2.

Although the structure of these vessels, both in relation to the shell and frames, is purely reinforced concrete throughout, the possibility of working the shell of reinforced concrete vessels in conjunction with ordinary frame bars or built-up frames has not been lost sight of, although the problems attendant on such a departure from a purely monolithic structure present difficulties. It is conceivable that a vessel might be satisfactorily constructed in which the ordinary steel frame is used in conjunction with the present system of reinforced concrete hull, and in the United States they appear to have adopted some such method. With our present knowledge there would appear to be in this connection an element of danger unless a system is used blending together the parts in such a way as to leave no possible chance of disruption. The experience gained by American builders in this respect may help to solve this difficulty, as the principle, if successful, appears to be well worthy of adoption. It may indeed be essential in reinforced concrete ships of large tonnage. Such a system, too, would overcome some of the difficulties in connection with the fitting of various details, which at present it is necessary to arrange for before the concrete portion is commenced. A further advantage, and probably the principal one, is that, without having to introduce a much greater proportion of skilled labour, the system would result in a decreased weight of hull.

Hull Fittings and their Connection.—Many problems have arisen regarding fittings and their connection and relation to the ship which in ordinary steel construction are simple, but which in the case of reinforced concrete construction offer difficulties which have had to be carefully examined and overcome. Amongst these are the openings in the ship's bottom, stuffing-boxes, the passage of pipes through bulkheads, the connection of fittings to the bulkheads, and the connection of stanchions, fairleads, bollards, etc., to the deck. Added to these are important problems, such as the connection to the hull of the rudder post, stern post, and the stern tube.

There is no doubt that, with experience, improved methods of adapting fittings and parts of the structure to their proper functions in economical and efficient manner will be evolved, but for the moment we think that the methods adopted are such as to give reasonable justification for anticipating efficient performance. In the case of a steel ship, if before the erection of the bulkhead provision has not been made and holes punched to take any particular fitting, as, for instance, a bracket, it is an easy matter to drill such holes afterwards to accommodate it. For a concrete vessel, however, the cutting of holes after the concrete has set is not easy and is undesirable. It is, therefore, highly important that all the details of fittings required to be connected to the hull, or passing through a bulkhead, for instance, should be considered before the erection and casting of that bulkhead, and the necessary information must be ready at an early stage of the construction in order that the builders may make suitable provision for the same when erecting the shuttering. Where it is necessary to leave a hole in the concrete, a wooden peg may be fastened to the shuttering in the required position ; but in the case of pipes passing through a deck or a bulkhead a better arrangement is to cast a metal spigot in the concrete with suitable flanges or screwed ends projecting on each side for connection to the pipes. Such fittings as mooring pipes or hawse pipes, as well as the majority of small topside fittings, have to be specially designed, with proper projections, for casting into the concrete, as otherwise holes must be prepared to take the holding-down bolts.

Lines and Tank Trials.—It is obvious, in view of the fact that the whole of the vessel's hull has to be cast in moulds or shutters, that the simpler and straighter the lines of the vessel the more cheaply and easily the shuttering can be constructed and the more rapidly the work can be proceeded with. For this reason, when designing the lines, a simple midship section was adopted having a perfectly straight side and bottom with only a very small curvature at the bilge. This section was retained in a parallel middle body for half the length of the vessel amidships, and the waterlines forward rounded into an easy entrance, still retaining, however, the straight-line sections. In rounding in the waterlines aft the straight-line sections were retained as far as possible and then run aft to the propeller and faired in with a minimum of curvature.

In determining the form two points had to be considered :—

(1) That the fullness of form which is economical in ordinary cargo boats when coupled with moderately low speeds would certainly be desirable when the material of construction was such that the weight of hull accounted for a larger proportion of the displacement than in the case of a steel ship.

(2) That the introduction of straight lines in the transverse sections, whilst desirable for constructional purposes, might lead to a large increase in resistance compared with an ordinary cargo-boat form, if there were any tendency for the stream lines to flow across the knuckle (*i.e.*, the intersection of the two surfaces forming the sides and bottom).

To obtain a reasonably good form under the above conditions trials were carried out in the experimental tank as follows : The model was made fuller than was actually required and cast thick enough locally to allow cutting off at certain parts. After the curve of resistance had been obtained with the original model (C S), the bottom part of the bow was fined (C S_2) with an improved result. Then the after-body was similarly fined (C S_3) with further advantage. A further fining of the bow (C S_4) and then again of the stern (C S_5) still improved the form, which was now reasonably comparable with an ordinary cargo-boat form of the same dimensions and displacement.

The total modifications made were comparatively slight, amounting to 23 tons, and reducing the block coefficient by ·01.

The load waterline and curve of areas have generally been regarded as the determining features of the resistance of an ordinary form, but we found that the influence of the knuckle was so marked that, with the waterline unaltered and practically the same curve of areas, a reduction was made in resistance of 40 per cent.

The lines ultimately adopted may, therefore, very reasonably be considered as the most suitable for simplicity of shuttering and for easy construction in reinforced concrete.

The deck has a camber of 8 in. in the full breadth ; but here again curvature has been avoided, the crown being a level flat 4 ft. each side of the centre line, the remaining deck sloping in a straight line to the side, and the deck at centre is a straight line all fore and aft.

Propelling Machinery and Boilers.—With respect to the propelling machinery, the considerations which have to be taken into account as to suitability of type are practically the same in reinforced concrete as in steel ships ; but the method of efficiently connecting the machinery to the hull of the ship, the arrangement of the stern tubes, the special attachment to the shell of sea connections, etc., require more consideration in the former case, and great care has to be taken to ensure reliability in this respect.

In the present six boats building to this design the adoption of machinery has been largely governed by what it has been possible to obtain under existing circumstances.

In three of the vessels we are fitting compound surface condensing single-screw engines of approximately 350–400 h.p. with cylinders 17-in. and 34-in. diameter, 24-in. stroke, working at about 100 revolutions per minute.

The boiler installation consists of two cylindrical boilers 9 ft. 6 in. diameter by 9 ft. long, working at a pressure of about 130 lb.

In the remaining three we intend fitting triple-expansion engines of about 500 I.H.P., which will somewhat reduce our deadweight capacity but give an appreciable increase of speed.

Two boilers were decided upon, so that in the case of a breakdown of one there would be sufficient boiler-power in the ship to drive the vessel at a reasonable speed. When in port one of the boilers will be of sufficient power to work all necessary auxiliary machinery, including that for loading or discharging. Incidentally, there are other advantages in having two small boilers, such as the possibility of their transport by rail instead of by sea from the place of manufacture to wherever the machinery is being installed. Further, the advantage of being able to ship the boilers through the hatchways, as leaving any part of the deck unfinished for this purpose, is very undesirable in reinforced concrete ships.

The machinery is fitted aft, a usual position in this type of cargo vessel ; but another reason for this was to reduce the length of tunnel, as if this were of reinforced concrete instead of steel it would form an important item of weight.

Launching.—Coming next to the question of launching, this is an operation which in the case of reinforced concrete ships requires more than ordinary consideration and care. This operation, always fraught with anxiety, is doubly so when dealing with a vessel of reinforced concrete construction. Take, for instance, the launching arrangements for the vessel under discussion. A launching weight of 1,100 tons has to be dealt with as compared with about 550 tons in the case of a steel ship of corresponding size. To keep down the stresses, a moderate declivity of ways with ample depth of water on the way ends has been arranged ; but even so quite a considerable hogging stress and excessive way-end pressures are met with just before the stern commences to lift. Some internal shoring has to be arranged at suitable parts of the vessel as additional precautions before launching. The shearing forces at the fore poppet are severe and must be met by an adequate strength of hull.

The foundation supports, especially as the vessel is being built on new ground, have been carefully considered, as sinkage during any stage of the concreting would have serious results and must be guarded against.

The precaution of allowing the concrete sufficient time to set properly before the vessel is launched is necessary in view of the fact that the compressive strength of the concrete continues to increase for some time after being worked, and it is necessary to utilise as much of this increased strength as possible to resist the launching stresses.

The supporting blocks and holding-up arrangements (dog shores) also require greater strength than is necessary in the case of the lighter steel vessels.

Generally speaking, the severe launching conditions may be taken as an adequate test of the vessel's ability to withstand any stresses she may be called upon to meet under ordinary conditions of service.

To obviate the undesirable necessity of pile-driving in the channel where the vessel is being built, the standing ways beyond the sea-wall are supported on specially designed pontoons resting on the bed of the channel. These pontoons are specially constructed of concrete, and may be towed from one berth to another, and when in the necessary positions are sunk by being flooded through sluice valves arranged in the sides for that purpose.

Some statement should perhaps be made here as to the time for construction of vessels of this type as compared with steel ships, and our experience so far leads us to believe that in the case of the first vessel of any type the time of construction approximates very closely to that of a steel ship, but that in building successive ships of the same size and form there will be a marked reduction owing to the possibility of using repeatedly a large proportion of the shuttering or moulds. By this means I believe that, with all the material to hand, a vessel similar to that described in this paper could be completed in three and a half to four months.

In conclusion, I should like to express a word of thanks to those associated with me in this work : the members of the staff of the Ferro Concrete Ship Construction Company, of Barrow-in-Furness, who have worked so energetically and untiringly in the design and construction of the vessels ; and to the directors and staff of Messrs. L. G. Mouchel & Partners, who have brought great ability and experience to bear on the solution of some of the difficult problems involved ; also to the directors of the Yorkshire Hennebique Company, who have by their experience shown us how, in many ways, the time of construction can be shortened.

MEMORANDUM on the USE OF CONCRETE FOR MINE SUPPORTS

By GEO. KNOX.

The following Memorandum, recently published by the South Wales School of Mines, Treforest, and prepared by Mr. Geo. Knox, Principal of the School, has a particular value at the present time when it is of the utmost importance to economise in the use of timber in every direction. We point specially to the part of the Memorandum dealing with concrete pit props, as this is a question deserving particular attention.—ED.

UNTIL recently timber has been the principal means of support used for underground workings, but owing to the continued rapid growth of the mining industry the available supply of suitable timber is difficult to obtain and costly to provide, particularly at the present time, when freight rates are so exorbitant.

The increase in cost and temporary nature of timber led to the introduction of brick and stone linings for main roadways, and of steel girders with wood lagging for secondary roadways. Brick and stone linings—particularly the latter—are too brittle to be of much service in ground where the strata have only partially subsided, and unless steel girders are put in very close together, with only light timber lagging, they are apt to be badly twisted, necessitating constant renewal. In ground which has completely subsided, particularly in return airways, brick, stone, or steel are preferable to timber on account of the time they will stand without renewal. For general roadway supports steel is cheaper than timber on account of the saving in renewals and freedom from falls of roof and sides.

During the past ten or fifteen years many Continental mining engineers have introduced concrete and reinforced concrete for shafts, galleries, tunnels, etc., with great success, and during the few years preceding the war, in Belgium and the Pas-de-Calais coalfields particularly, the use of concrete had become extensive, replacing almost entirely the use of brick, stone, or steel for permanent supports.

In discussing this matter with several Continental engineers who had adopted this process they all expressed surprise that it had not been adopted on a large scale in Britain, as it had proved an assured success in their collieries, their claim being that it

(*a*) Was cheaper and superior as a means of support.
(*b*) Reduced stoppage in haulage to a minimum.
(*c*) Produced smooth, airtight roadways which in dusty mines could easily be kept clean and safe by watering or dust extraction.
(*d*) Reduced leakage in ventilation.

The first attempt at forming concrete linings on the Continent was by making reinforced blocks and building as in the case of bricks, but this was found to be costly and less stable than the method now used of forming the whole lining of "concrete puddle" behind a framework which was allowed to remain in for about fourteen days before being withdrawn. By this time the whole of the concrete has set in one complete block, and if reinforced with old wire ropes, etc., will stand a greater pressure than either stone or brick linings.

Underground concrete lining, to be cheap and successful, must be constructed of materials suitable to the conditions prevailing in each particular case. In wet ground, for example, it would be useless to use ordinary lime, whereas in dry workings cement need only be used in very small quantities (about one part of cement to eight of lime). Again, in ground where a heavy crush was expected, or in large excavations such as pit-eyes, the "aggregate" should consist of hard rock, whereas under ordinary circumstances the shale from the mine rippings will be found strong enough. The amount of reinforcement required will also depend on local circumstances, being greatest in large excavations or in subsiding or faulted ground.

In choosing cement use always the best class possible, which can be determined by its fineness, specific gravity, and tensile strength. In very particular work, where strength is the all-important factor, the cement may be improved by re-grinding immediately before being used. Where rapidity of setting is required (initially and finally) cement should be re-ground very fine. If, however, the cement and aggregate had to be mixed on the surface and sent into the mine in trams, slow-setting cement should be used, as concrete which becomes "dry" and has to be re-mixed is as friable as bricks.

Where great strength is required the best concrete is made from the following:—

9 parts—36%—1½″ granite.
8 ,, —32%— ½″ granite.
5 ,, —20%— sand.
3 ,, —12%— cement.

In dry underground roadways the concrete may consist of:—

1 part — 3%—cement.
8 parts—23%—freshly burned lime.
24 ,, —74%—hard shale from ripping up to 1½″.

In other words, the strength of concrete depends upon the hardness of the aggregate and the purity of the cement, and the cost will be determined likewise.

Continental engineers say that cement and lime should never be mixed in concrete, but I have seen the mixture used successfully in several cases in this country, and only on one occasion did I know of its failure, and in that case the lime had been lying in the store for a considerable time, which in all likelihood accounted for the failure.

Where cement only is used fine material (stone and sand) must be mixed with the coarser aggregate, so that all the interspaces are roughly filled with only a thin layer of cement between the parts to consolidate them.

Careful mixing is very important to ensure successful results. Where this is done by hand (as will be the case in the experimental stage) it should be carefully turned over when dry until well mixed, and the process repeated again when wet, care being taken to keep it free from any oil, grease, or slimy muds. For this reason it will be better to have the dry mixing done on the surface and conveyed underground in trams to the place where the concrete is required, when the wet mixing could be carried out.

When putting reinforced concrete in position it is best to shovel it in against either side (from the bottom upwards), allowing it to come to rest at the angle of repose, and during this process the reinforced bars (old ropes usually) should be jarred occasionally by knocking with a hammer, so that the whole space has an opportunity of getting completely filled.

Concrete has a low tensile strength, but fortunately for its use in mines compressive strains are what have to be most frequently guarded against, and its strength in compression is much higher than brick or stone. Ordinary concrete (without reinforcement) is three to five times as strong as the best brick, and five to eight and a half times as strong as ordinary brick :—

	Laid in best mortar.		
	Ordinary brick.	Best brick.	Concrete.
Compressive strength in lbs. per square inch	486	834	2,000 to 4,000 after 1 month.

On the Continent the mixtures most frequently adopted are as follow :—

	Cement.	Sand.	Rock.	Compressive strength in lbs. at end of 1 month.
For vertical walls	1	1	2	4,000
Retaining walls	1	1½	3	3,400
Shaft linings	1	2	4	2,700
Engine, etc., foundations	1	2½	5	2,300
Underground dams	1	3	6	2,000

As illustrating the effect of reducing the percentage of cement and increasing the percentage of sand, the following results were obtained from experiments recently carried out :—

Proportion of Sand	0	$\frac{1}{2}$	1	1½	2	3	4	5	6	7	8
Comparative Strength	1	$\frac{2}{3}$	$\frac{1}{2}$	$\frac{2}{5}$	$\frac{1}{3}$	$\frac{3}{10}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{7}$	$\frac{1}{8}$

To show the value of re-grinding to produce a quick-setting concrete, the following results may be quoted :—

Sample.	End of 24 hours.	End of 7 days.	End of 28 days.
	lbs. per sq. inch.	lbs. per sq. inch.	lbs. per sq. inch.
Ordinary	135·9	555·3	657·8
Re-ground for 5 hours	318·0	508·3	631·3
Re-ground for 14 hours	305·0	509·7	598·8

The relative cost and strength of wood, brick, sandstone, and concrete are given by Habets in "Course d'Exploitation des Mines" as follows :—

	Wood.	Sandstone.	Brick.	Concrete.
Cost per metre in francs	130	120	32	[illegible]
Resistance in kilos per sq. c. ...	45	80	12	30
Cost per cubic yard	£4 11s. 6d.	£3 13s. 3d.	18s. 10d.	12s. 3d.

Where mine rubbish is used to form the aggregate the cost of material is about :—

s.	d.	
7	2	per cubic yard for 6-1 concrete (cement).
8	2	,, ,, 5-1 ,, ,,
4	0	,, ,, 4-1 ,, (lime).
3	2	,, ,, 5-1 ,, ,,

Mixing, transit, and fixing would cost 3s. to 5s. per cubic yard, according to the nature of the ground to be filled in. Adding to this the fixing of the "cradling" or "centreing" and the old rope strands for reinforcement, the cost would probably be at the present time between £4 and £5 per linear yard of roadway 9 ft. by 7 ft.

Where cement only is used to consolidate the aggregate, care should be taken to prevent dust adhering to the rock forming the aggregate before mixing. If the material used produces a lot of dust in the crushing, the aggregate should be sprayed (or, better still, subjected to a jet of compressed air) to get rid of the dust. Where a mixture of lime and cement is used this is not necessary. One of the best materials to be had in colliery districts from which the aggregate may be constructed is the burned shale from colliery rubbish tips. It is harder than ordinary shale, is rougher on the surface, and therefore gives a better surface for the cementing material to adhere to. When mixed with ground furnace slag it forms an excellent aggregate for concrete. In many cases boiler clinker is used to mix with the mine shale. It is crushed and passed through a ⅝-in. mesh. This fills the interspaces between the pieces of coarser shale, but as clinker has only a very low strength in compression it is not advisable to use it if a plentiful supply of hard mine shale can be obtained.

Where side support is required (as well as roof support), the concrete lining should be put in as shown in rough sketch (*Fig.* 1), so that all of it comes into compression when weighted. On the Continent, where the main roads are concreted, this work is done as soon as the maximum of subsidence has been reached, and as the road is then ripped to get the required height the finished area remains practically constant. It is therefore an advantage to have "centres" or "cradles" constructed as shown in *Figs.* 1 and 2, as in use at Bethune Colliery, where the cross staff can be withdrawn, allowing the whole thing to collapse and be carried forward for re-erection.

Where the area of roadway is very variable this would require too much concrete to fill up the intervening space. It is therefore advisable to have some form of frame which can be expanded (as shown in *Fig.* 3) to suit the local conditions. This is essential where reinforced concrete is being substituted for other supports (in repair work), particularly where large falls of roof have taken place.

The cheapest reinforcement for this kind of work is the strands of old steel haulage and winding ropes. Under normal conditions it may only be necessary to put the strands in longitudinally, but where extra support is required it is advantageous to have them crossed with transverse strands, as shown in *Fig.* 4, and with very bad roof weights two sets of longitudinal and transverse strands may be put in together, with a few extra longitudinal wires between the sets. An important point to note in connection with the reinforcement is that the ends of the strands should terminate irregularly so as to overlap the next set at different points and prevent anything in the nature of a "joint" being formed.

Where the sides are strong enough to make a foundation for the "quarters" it is not at all necessary to cut away the sides, but it is a wise precaution to protect them from the effects of atmospheric weathering by a thin layer of concrete, as shown in *Fig.* 5. The concrete arch may then be sprung from this (as shown on sketch), thus saving a large amount of excavation.

Where concrete arching breaks on account of excessive or sudden pressure it does so as a rule at the crown of the arch, and less frequently where the arch rests on the quarters. In the former case you may either get a sharp fracture, which can usually be filled up with neat cement, or splintering, when the concrete comes down in flakes until the reinforcement is exposed. In this case the temporary "cradle" or "quarters" should again be erected, and after the fractured surface has been coated with cement concrete should be rammed in to fill up the space between the roof and the cradling.

In the initial experimental stage the aggregate will probably be broken and sized by hand, and the cement and lime be obtained from the market, care being taken that only the best cement is used, and that the lime (which should be freshly burned) contains at least 80 per cent. CaO, which can easily be obtained from the best lias limestone. Only the amount required should be wet mixed, as re-mixing makes it brittle and useless.

Should it be decided to adopt this method on a large scale it would be much cheaper to erect special lime kilns at the colliery, when the lime could be calcined by means of the refuse from the washery, the ash of which assists in strengthening the aggregate. A stone crusher and screens would also be required, together with a screw conveyor to convey and mix the material before sending it into the mine. It will be time enough to consider this matter once an experiment had been carried out and the success of this was assured, but it should be remembered that the cost of an experiment made by hand where the workmen are all new to the work will be much more than where the crushing and mixing is done mechanically and labourers have been trained to fix the material.

Reinforced Concrete Props.—For some years past reinforced concrete props have been used in the Midland coalfield. They are made in moulds, and usually consist of one part cement, one part boiler clinker (through $\frac{5}{8}$-in. mesh), and two parts breeze dust. They were made in lengths up to $5\frac{1}{2}$ ft., and reinforced by several strands of small haulage ropes. They were kept in the mould until set, then staked and watered daily for a period of four to six weeks before being used. When made in very large numbers and using aggregate as above they cost in pre-war days about 8d. each. As the compressive strength of the aggregate was low, and no special method of binding the reinforcement was used, these props had a very low breaking strength.

Many improvements have been effected in the manufacture of these props during the past four years, and some colliery companies are making these props, at the rate of 1,000 per week, in lengths varying from 3 to 9 ft The Lilleshall Co., Ltd., make the following sizes for sale :—

Length.	No. of props per ton.	Price. s.	d.
4′ 6″	31 approximately	2	9 each
5′ 0″	28 ,,	3	0½ ,,
5′ 6″	25 ,,	3	5 ,,
6′ 0″	23 ,,	3	9 ,,
6′ 6″	15 ,,	4	10 ,,
7′ 0″	12 ,,	5	3 ,,
7′ 6″	10 ,,	5	10 ,,
8′ 0″	8 ,,	6	5 ,,
8′ 6″	7 ,,	7	0 ,,
9′ 0″	6 ,,	8	6 ,,
10′ 0″	5½ ,,		

The following tables show the results of experiments to ascertain the resistance to thrust of reinforced concrete props made by the Lilleshall Co., Ltd. :—

TESTS MADE BY MESSRS. DAVID KIRKALDY & SON, 99, Southwark Street, London.—21.3.16.

Test No.	Description.	Length.	Dimensions.	Base Area (Approx.).	Ultimate load per sq. in.		Remarks.
			inches.	sq. ins.	lbs.	tons	
YY	Ends of Props only roughly squared. Tested against 9 in. × 3 in. deal walings						Failed at mid length.
1402	Wooden Pit Prop (Norwegian Larch).	5 ft. 10¾ in.		30·7	2670	1·19	
1403	do.	5 ft. 11¾ in.		26·0	4080	1·82	Failed at one end.
1404	Reinforced Concrete Pit Prop (3 Vertical Rods ⅜ dia.). A.	6 ft. 0 in.		18·5	3840	1·71	Failed at mid length.
1405	do. B.	6 ft. 0¼ in.		17·5	3540	1·58	Failed at one end.

The load in this case was applied at the rate of ten tons per minute.

TESTS MADE AT THE SCHOOL OF MINES, TREFOREST.—26.9.17.

Prop.	Length.	Section.	Sectional area sq. ins.	Load at which props first gave signs of failure.	Final load taken lbs.	Load taken in lbs. per sq. inch.
A	78 in.	5 in. × 5 in.	25	40,000	48,200	1,928
B	78 in.	5 in. × 5 in.	25	24,000	44,000	1,760
C	54 in.	5 in. × 4½ in.	21 Allowance for corners.	40,000	45,000	2,140

The load in this case was applied at the rate of one ton per minute.

It is interesting to note that a comparison of the above tests confirm the statement that the greater the rate of loading the higher the load taken by concrete.

These props would have borne a still greater load if the binding wires round the reinforcement rods had not been placed too far apart at the ends, which allowed a fracture to develop between the two interlacing wires.

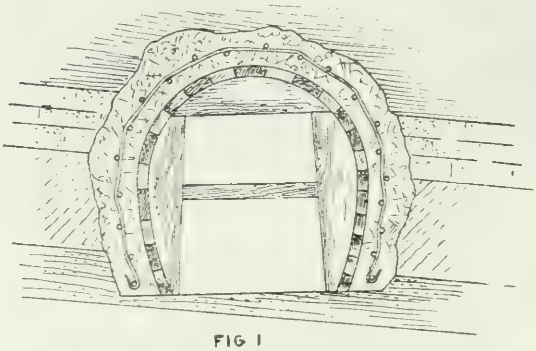
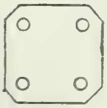


FIG 1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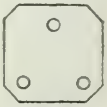
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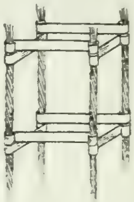
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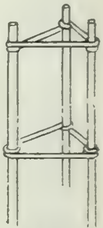
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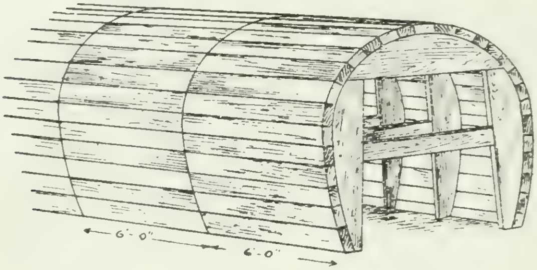

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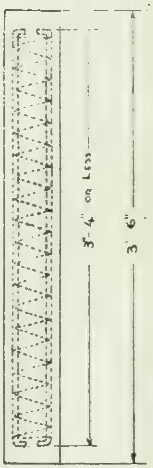


FIG 8

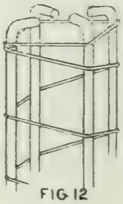


FIG 12

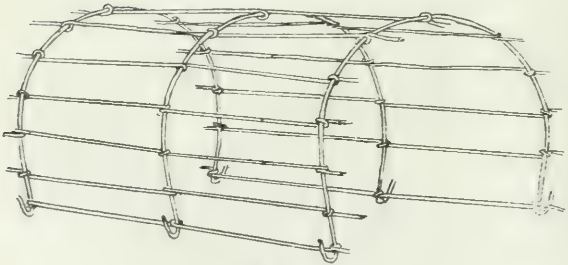


FIG 4

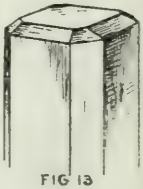


FIG 13

FIG 9

Their colliery manager states that "no objection has been taken by the workmen to the use of concrete props, and that in practice sufficient warning is always given before breaking through pieces of concrete flying from the sides of the props." "The price of these props," he says, "compares favourably with that of wood, and that wet does not affect them."

Several colliery companies in South Wales have recently attempted the manufacture of concrete props, and the following results of tests made at the School of Mines, Treforest, of props constructed at Tynebedw Colliery will show that even in the initial stages fairly satisfactory results may be attained.

TYNEBEDW COLLIERY.—RESULT OF TEST ON REINFORCED CONCRETE PIT PROPS.

Prop.	Mixture.	Reinforcement.	Length.	Section.	Time of setting days.	Load at which prop first gave signs of failure (lbs.).	Trial Load (lbs.).	Remarks.
A	⅓ cement and ⅔ burnt rubbish from tip	¾ in. diameter haulage rope through centre.	3 ft. 6 in.	3½ 3½	20	9,700	15,900	Poor method of Reinforcement.
B	do. do.	6 strands of wire rope placed in parallel pairs, 2 in. apart; diameter of strands 0·3 in.	3 ft. 6 in.	4 3½	15	—	19,300	Coarse material present. No interlacing of Reinforcement.
C	do. do.	do.	do.	do.	48	17,400	17,800	Coarse material present. No interlacing of Reinforcement.
D	⅓ cement and ⅔ boiler clinker.	do. but interlaced with No. 16 wire (slightly).	do.	do.	37	24,000	30,200	
E	do. do.	do.	do.	do.	31	19,300	34,600	Kept under water while at School of Mines.
F	(Wood) ..	—	3 ft. 6 in.	4 in. dia	- -		41,800	

In the construction of concrete props the nature of the aggregate used and the methods of reinforcement are the most important points to be considered in turning out a satisfactory pit prop. A good mixture consists of cement, boiler clinker, and burnt colliery tip rubbish, in the proportion of :—

One-fifth cement (fresh and finely ground).
One-fifth boiler clinker (between $\frac{1}{16}$ in. and $\frac{1}{8}$ in.).
Three-fifths burnt colliery shale (between $\frac{1}{8}$ in. and $\frac{1}{4}$ in.).

These ingredients should be well mixed before being put into the moulds and carefully rammed all round the reinforcement to ensure good binding.

The reinforcement need not consist of more than three or four thin steel rods from old guide rods (or old wire rope strands), placed as shown in plan, *Figs.* 6, 9, and 10, and interlaced as shown in section, *Figs.* 7, 8, 11, and 12.

Care should be taken to have the binding pieces sufficiently close together at both ends to prevent the prop splitting. It is also necessary to note that the reinforcement at both ends should be covered by at least one inch of concrete (see *Fig.* 8), otherwise the weight or pressure acting directly on the reinforcement causes the prop to bend and break up with a comparatively small load. Chamfering the top as shown in *Fig.* 13 also tends to prevent splintering.

The whole question of the cost of temporary support at the faces is largely determined by :—

(*a*) The rate at which the faces advance; and
(*b*) The amount of permanent packing put into the gob.

Reinforced concrete props could be most advantageously used where the faces move forward rapidly and where a maximum amount of permanent packing is put into the gob. Under these conditions the amount and rate of subsidence between the face and the packs is reduced to a minimum and acts slowly and steadily. With moderately careful handling, setting, and withdrawal, these props would last for a considerable time.

In South Wales collieries a fairly large proportion of the total supply and the heaviest of the timber is used for repair work on the main roadways. This could be largely replaced by the erection of reinforced concrete arching on the lines suggested above.

The estimated quantity of timber used in the mines of this country annually is normally 4,500,000 tons, of which four-fifths, or 3,600,000 tons, is imported overseas. Apart from the necessity of saving every possible ton of shipping, the increased cost of timber must be considered. During the past three years the total cost has been enormously increased, although the quantity of timber imported has decreased.

In 1914	imported	timber cost	£3,259,346.
,, 1915	,,	,,	£4,786,361.
,, 1916	,,	,,	£6,908,091.

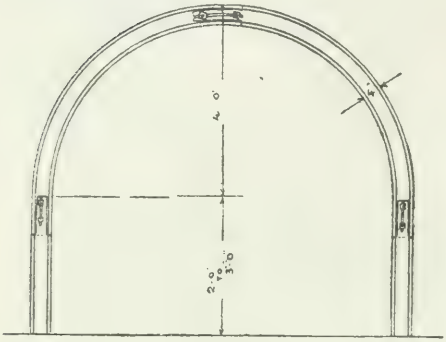


FIG 3

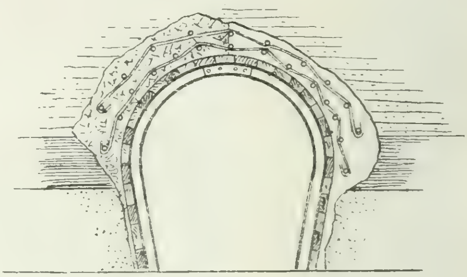
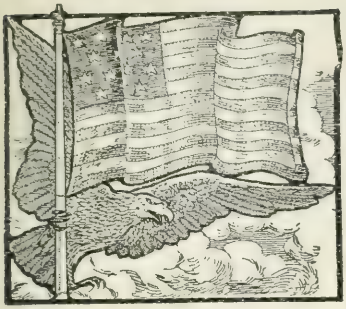


FIG 5

Under these circumstances it seems evident that steps should immediately be taken to reduce the tonnage required for timber imports, and at the same time reduce the cost of supports for mines.

The use of reinforced concrete, particularly in the form of arching in underground roadways, is not a highly skilled undertaking, and there is an abundant supply of suitable material to be had in every district in the coalfield if only some definite scheme could be put into operation to make use of it.

The number of men who have been withdrawn from the mines for the purpose of felling trees in the most inaccessible districts in North Wales, had their services been organised for the purpose of providing a reinforced concrete substitute, could have produced more satisfactory results at a less cost, and instead of disfiguring the country might have been establishing a permanent industry in this district and ridding some of our valleys of their unsightly rubbish heaps.



REPORT OF THE JOINT COMMITTEE OF THE AMERICAN CONCRETE INSTITUTE AND PORTLAND CEMENT ASSOCIATION ON CONCRETE BARGES AND SHIPS.

The following concluding part of the Report prepared by the Joint Committee mentioned above puts forward a tentative design for a concrete barge, and refers generally to design questions.—ED.

TENTATIVE DESIGN FOR A CONCRETE BARGE.

BOATS or ships devoted to carrying of cargo may be divided, for the purpose of this report, into two general classes: those adapted to use in still waters, such as harbours, rivers, and canals; and those adapted for use at sea, in which provision must be made for wave action.

Your Committee devoted much thought and study to the question of what type of ship would be most suitable for study at this time.

Ships for use in still water do not present the same problems of construction as do ships for ocean service. Owing to the need of barges of from 100 to 150 ft. in length for use on the canals of New York State, it was your Committee's first thought to devote study at this time to the design of a barge which would be suitable for this service. After considerable study and discussion with various naval architects, including the firm of Cox and Stevens, of New York, who were retained by your Committee in an advisory capacity, it was deemed advisable to abandon the study of a small still water barge for the reason that while such a study might result in considerable information as to the best method of construction and dead weight compared to displacement, the problem, which is of vital importance to solve at this time—namely, whether or not concrete can be adapted for ships necessary for trans-Atlantic and coastwise service as well as possible service on the Lakes—would remain unsolved, and little or no information would be obtained bearing on this phase of the question. It was therefore decided to devote the study to a ship of the sea-going type. In order to simplify the problem as far as possible without omitting any essential elements, it was decided to select a barge to be towed rather than a self-propelled ship. This would eliminate all consideration of weight of all boilers and engines excepting such as would be required for auxiliary hoisting machinery. Because of the fact that so little is known regarding the concrete ship it was deemed advisable to keep the ship as small as possible. It was thought at first to limit the size to an assumed carrying capacity of 1,000 tons or less.

After many conferences by your Committee with its consulting naval architects it was decided to increase the capacity to about 2,000 tons, it being the decided opinion of the naval architects that a ship smaller than 2,000 tons would have little commercial value after the war, although during the war it would probably prove successful.

In the absence of any reliable data as to the relation between dead weight and displacement for concrete ships an assumption was made that the dead weight would be approximately 55 per cent. of the displacement for the proposed tentative barge. Upon this supposition the consulting naval architects laid out the lines for the proposed ship. The dimensions are as follows:—

	Ft.	In.
Length (over all)	227	6
Length between perpendiculars	220	0
Beam	42	0
Depth	23	0
Loaded draught	18	0

The hull was given lines such as would provide maximum carrying capacity and still permit reasonable towing and adequate control. At an 18-ft. draught the displacement will be about 3,675 tons, at 19-ft. draught the displacement will be about 3,860 tons.

The general dimensions of the barge and the lines are indicated in the diagrams on page 260. It should be noted that the mid-ship section of the hull is rectangular with the exception of a slight crowning of the deck and a slight inclination of the bottom upward toward the bilges (dead rise). The deck is straight throughout and continuous from stem to stern. The ship is divided into five compartments by four transverse bulkheads, the foremost and aftermost compartments are to be used for tanks and ballast, while the three centre compartments are for cargo. The cargo compartments served by three hatches, each about 14 ft. by 19 ft.

DESIGN.

As has already been noted, the actual stresses in the structural members of a cargo ship are not usually computed, but sections are adopted which long experience has shown to be safe.

After consultation with the naval architects it was thought desirable to take as a criterion a steel ship designed in accordance with the rules as laid down by Lloyd's, and provide equivalent strength in reinforced concrete, with such modifications as the difference in material would make necessary. Assuming that the concrete for the ship would be poured as in a concrete building, a limit of 3 in. was placed upon the thickness of the concrete, as that was considered the minimum thickness that can be poured satisfactorily.

The question of weight being vital in the design of a concrete ship, it was deemed desirable to assume a concrete of high crushing and shearing strength. A concrete of one part Portland cement and one part carefully selected sand and two parts selected gravel (about ½ in.) was decided upon, which, if properly mixed, should give an ultimate crushing strength in excess of 3,000 lbs. per sq. in. The stress in the concrete in extreme fibre was limited to 1,000 lbs. per sq. in. In order to reduce the danger of cracking the concrete in extreme fibre a large percentage of steel was assumed with a resulting low tensile stress.

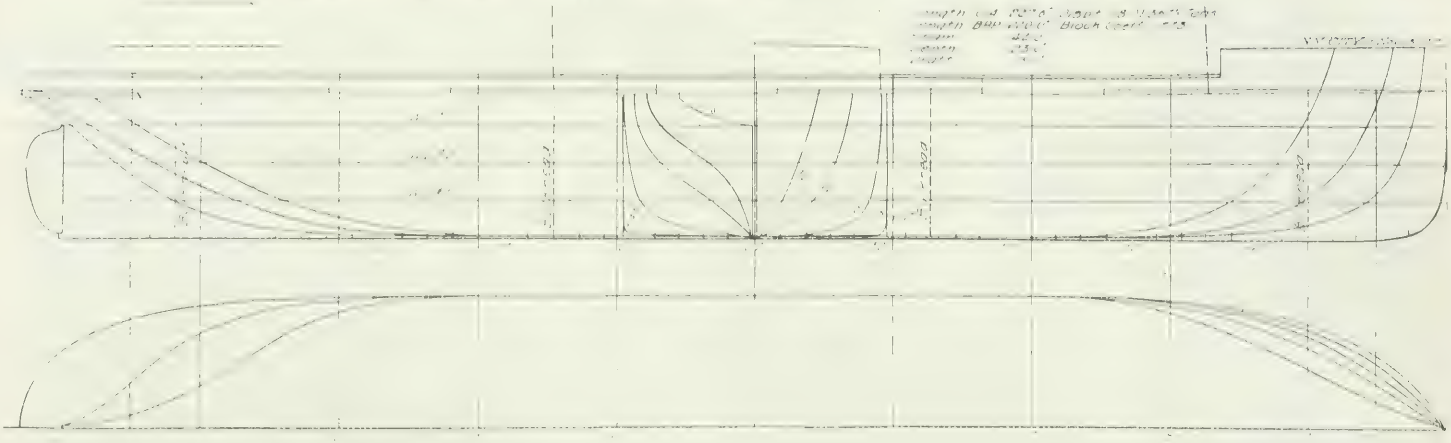
For a ship of the same size Lloyd's rules require that the ribs or frame be placed 24 in. on centres. This was deemed too close for economical use of concrete, and a spacing of 4 ft. was adopted, making the resisting moment of each frame at all points equivalent to twice the resisting moment of one frame in the steel ship. In determining the strength of the frames of the steel ship as fixed by Lloyd's rules no allowance was made for the effect of the tank top (floor of the hold) or of the bottom plating. Assuming a spacing of frames of 4 ft. and a resisting moment equivalent to two frames, under Lloyd's rules the floor plate or transverse girder supporting the ship's bottom was found to require a concrete girder 36 in. deep and 10 in. wide. including the bottom slab.

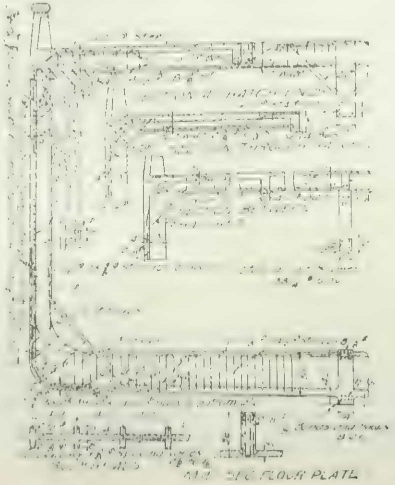
To provide for the negative and positive bending moment in the shell, two lines of reinforcement was assumed—one near the outer surface and one near the inner surface. The load being uniform, the positive bending moment at the centre between frames will be approximately one half of the negative bending moment at the frames. Two-thirds of the total amount of steel was therefore provided near the outer surface and one-third near the inner surface, all the bars being straight, it being considered impractical to bend the bars. From the lower turn of the bilge up to the deck one size of bar was assumed, with variable spacing to meet the required strength at different depths. The thickness of the shell from the upper turn of the bilge to the rail was fixed at 4 in. To provide adequate strength against "hogging" or "sagging" tension steel to the extent of 140 sq. in. was provided in both deck and bottom. This steel was considered also as providing reinforcement for local stresses in the bottom due to hydrostatic pressure and in the deck due to load. It was placed in two layers to take up both negative and positive moments, two-thirds being near the outside surface and one-third near the inner surface. Since this steel will be subject to compression as well as tension, the two layers were securely tied together to prevent buckling. To provide adequate protection to the steel, and also to provide sufficient area in concrete to take up the compression stresses, the thickness of the bottom up to the upper turn of the bilge was made 5 in. The deck between the bulwark and the line of the hatch coamings was made 5 in. also. The deck between hatches and within the lines of the hatch coamings was made 3 in. thick. The deck itself not being sufficient to provide sufficient area in concrete, additional area was added at the junction of the deck and the sides, where it would also tend to increase the resistance to horizontal shear, which would be high at that point.

In the bottom three longitudinal members running from bow to stern were provided—one on the centre line and one at each lower turn of the bilge. These longitudinals, or "keelsons," give longitudinal stiffness, assist in distributing the load due to dry-docking, and provide additional area for hogging and sagging stresses.

The vertical frames in the sides were made 7 in. wide and 17 in. deep, including the shell, and an equivalent in strength to steel frames under Lloyd's rules. At the junction between the floor plate and the side frames a heavy gusset is provided to give additional strength at that point. A similar gusset is provided between the side ribs and the deck beam. This gusset is increased

Suggested Lines for 2000 Ton Sea-going Reinforced Concrete Barge accompanying Report of the Joint Committee on Concrete Ships and Barges of the American Concrete Institute and Portland Cement Association.





Some Details of the Proposed Design for Sea-going Concrete Barge.

in size at the beams at hatch ends. The deck along the centre line is supported by means of posts at the ends of each hatch and at alternate deck beams between hatches.

The bulkheads consist of 4-in. slab reinforced near both surfaces and stiffened by reinforced ribs 20 in. in depth over all and 7 in. wide, spaced 4 ft. on centres.

The general features of the concrete design are indicated in the diagrams on page 260.

ESTIMATE OF QUANTITIES AND WEIGHTS.

A conservative estimate of quantities required for the proposed barge gives the following:

Concrete	731 cu. yds.
Steel	482,000 lbs.
Yellow Pine Timber for floor of hold...	30 M' b.m.
Oak Timber for fender and rail.........	15 M' b.m.

Taking the weight of concrete at 144 lbs. per cu. ft., weight of steel 490 lbs. per cu. ft., and weight of wood 48 lbs. per cu. ft., and making an allowance of seventy-seven tons for deck machinery, anchors and chains, spars, water tanks, and deck houses, the total weight of ship would be 1,647 tons. Taking the displacement of 18 ft., draught at 3,675 tons, the carrying capacity, or dead weight, would be 2,028 tons. Assuming 19 ft. draught, the displacement would be 3,860 tons and the dead weight capacity 2,213 tons.

COST.

Assuming sand, stone, cement, and reinforcing steel at current prices, the cost of the hull (exclusive of any equipment such as deck houses, spars, anchors and chains, engines, boilers, and tanks) would approximate $118,000. Assuming the construction of ways which could be used for the construction of five or more ships, the cost of ways per ship would approximate $8,000, making a total cost of the hull (exclusive of equipment) $126,000.

Based on the figures noted above, the cost of the hull per ton of dead weight would approximate $63. Owing to a wide range in costs of steel and wooden ships of the same character, it is somewhat difficult to arrive at anything approaching a definite estimate for steel or wood ships. The best figures available seem to indicate that the cost of steel hull per dead-weight ton ranges from $90 to $120, while the cost of a wooden hull ranges from $70 to $100.

OTHER TYPES OF CONCRETE SHIPS.

The designs of various other types of ship in which reinforced concrete has been proposed either alone or in combination with structural steel were examined by our Committee.

In some of these designs cellular sides and bottoms are proposed. Although double side and bottoms in ships have distinct advantages, when the material is concrete such a design appears out of the question not only because of the considerable increase in weight, but also because of the added complication to the form work, already a large item in the cost of a concrete ship.

Designs have been proposed in which structural steel members are used as reinforcement. While such members assist somewhat in maintaining the lines of the ship during the construction of the form work, the added advantages can hardly offset the increased cost due to the fabricated steelwork and the inefficient use of the reinforcement.

One design has been proposed in which structural steel members are used to support a shell of reinforced concrete. While the claim is made that a ship can be built of the proposed design with only about one half the steel used in a steel ship of the same capacity, and at much greater speed of construction, the difficulty of making the two materials act together, thus avoiding cracks, makes the design as proposed of doubtful value.

Your Committee feels that it is not its function at this time to prepare any detailed plans for a concrete vessel. It is manifestly impossible to design a type of vessel that will be applicable to all classes of service. A barge for use on the canals of New York would not be an efficient type for use in harbours or on the Ohio or on the Mississippi.

Vessels heretofore built have demonstrated that the small barge for still-water service can be built and successfully operated. The solution of the larger problem of a concrete ship will include the solution of smaller vessel problem, in which questions of strength are not of the same prominence.

Although there are some questions regarding the concrete ship which can only be answered by actual experiment, the studies which your Committee has made point to the commercial success of the concrete ship.

Your Committee suggests that specifications for a concrete vessel should embody the following principles :—

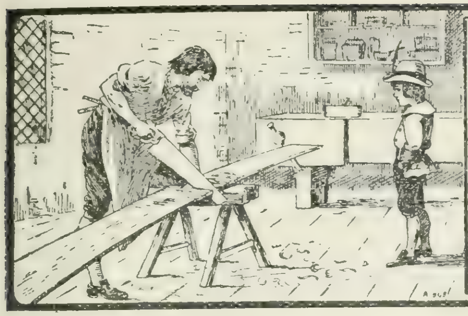
1. Both cement and aggregates should be selected with great care, to insure a concrete of maximum efficiency.

2. The concrete should be placed in one continuous operation, to insure monolithic construction. The concrete mixture should be such as will develop a crushing strength in excess of 3,000 lbs. per sq. in. when tested in standard cylinders at twenty-eight days. A concrete consisting of one part Portland cement, one part sand, and two parts ½-in. aggregate may be expected to give such a concrete. The mixture and workmanship in placing must be such as will assure impermeability.

3. The reinforcing steel should be in the form of deformed bars and should be galvanised.

4. In parts of the vessel where cracks in the concrete would tend to cause leaks the stress in the steel should be kept low (preferably less than 12,000 lbs.).

5. Some form of elastic waterproofing coating should be applied to the hull below the deck.



CONCRETE SIMPLIFIED.

By THOMAS POTTER.

A Practical Guide to the General Use of Concrete.

(*Continued*)

The first three articles of this series appeared in our February, March and April issues.—ED.

X.

THE COST OF CONCRETE—SHRINKAGE.

THE cost of concrete will be largely affected by the question as to whether a suitable aggregate is available on or in the vicinity of the site, this applying to both coarse and fine aggregate, as the cost of transport will be a serious consideration when the material has to be obtained from a distance. The market price of Portland cement will need to be taken into account, while water is also a matter for consideration. The cost of labour is so uncertain at the present time and in the future that an approximate estimate even would probably be misleading—it depends on so many circumstances. The writer never found any difficulty in making friendly arrangements with farmers in agricultural districts for the loan of some of their workmen when not too busy, and when so employed an extra sixpence a day above their usual wages—for work of this description is laborious—was well laid out. Obviously a foreman who has had some experience in the use of concrete is a *sine quâ non;* for work of an unpretentious and straightforward character it is possible he may be employed for a fixed period only to teach one of the more intelligent workers the elementary knowledge required to take his place—one possessing the desirable qualifications of common sense and the careful handling of men and materials. With practice the agricultural labourer of the better class is by no means deficient in these essentials, and some have developed to become expert practitioners, and eventually supervised important concrete constructional work elsewhere. As a rule he has no opportunity of bettering his position; concrete practice enables him to do so at times.

An important element in cost is what is known as shrinkage; not that any of the materials employed expand or contract in themselves, but the addition of water, the intermixing of the ingredients by the shovellers, and the tamping or punning they undergo while being deposited in place cause them to interlock and slide into a dense or homogenic condition, and as a result to occupy less space than previous thereto. Neither lime nor cement increases the bulk; their particles fill up the interstices too large for the sandy portions of the aggregate to effect. This shrinkage depends a good deal on the form of the aggregate—*i.e.*, whether it is of a round or pebbly shape or of that of rough cubes with their angles and corners knocked off similar to when produced by a steam crusher. The shrinkage in the latter case is considerably less than in the former.

Many years since Professor Hayter Lewis, with a view to ascertaining the amount of shrinkage, said, in a paper he read on the subject, that he was present where a test was made with six parts of Thames ballast as received and one part of ground lime, and the result was no shrinkage. On the other hand, Mr. Goodwin, who built some large warehouses in Southwark Street of concrete made of similar materials and in similar proportions, found the shrinkage to amount to 15 per cent. Messrs. Cubitt and Co. stated that their experience was similar thereto, and Messrs. Lucas that gravel excavated for the foundations of Covent Garden Theatre shrank 4 per cent. and Thames ballast 6 per cent. The formula of the London County Council—Thames ballast or pit gravel none larger than will pass a $\frac{3}{4}$-in. mesh, with a certain proportion of sand added thereto and included in the measurement—is said to shrink 20 to 33 per cent., an important item in a large contract. In a general way concrete made with coke breeze, boiler ashes, and crushed brick and tile yard *débris*, and similar materials, may be assumed to shrink 10 to 15 per cent. when wet and 15 to 20 when dry. It may happen at times that the aggregate is delivered in carts supposed to hold a cubic yard, but which is not always the case, and which will help in a measure to account for these and similar discrepancies.

EXPANSION AND CONTRACTION.

All building materials expand and contract with temperature changes, and the reason for these not being noticeable in brick and stone walls is that their innumerable mortar joints enable the change of form to be so distributed as to be unnoticeable. Monolithic concrete walls, however, being of the nature of a single stone, are liable to develop vertical cracks at intervals when the temperature falls and which close when it rises. These are not so apparent in the walls of cottages and other buildings exposed on one side only, but are more frequent where the walls are exposed on both sides. Stopping the cracks with cement is of no avail; they recur again and again. In the first building I erected many years since, and without any previous knowledge of concrete, I inserted in the walls a considerable quantity of iron hoop under the mistaken impression that the concrete alone would be of insufficient strength otherwise, but the result of which was that they have always been free of temperature cracks, as explained in Chapter V. In Reid's "Practical Treatise on Concrete," published in 1869—the first of its kind published in this country—no mention is made of shrinkage, and in a well-known builders' price book for the same year concrete is said to require the aggregate and cement to be each measured separately, and these added together will give the actual measurement of the concrete when in place—a fallacious statement.

CONDUCTIVITY AND CONDENSATION.

It was a general opinion at one time that concrete walls were colder than brick walls, but the result of experiments made by the United States Government was that houses with concrete walls were 5 to 10 per cent. warmer in winter and cooler in summer than brick houses similar in size and otherwise.

Concrete walls when plastered are as a rule considered to be more susceptible of condensation than brick walls, but this has not been my experience after twenty years' occupation.

For three months after erection there was occasional evidence of condensation, but at no time afterward. The water contained in concrete must evaporate externally, the result of wind and sunshine, and internally the result of domestic fires and air currents, and until this is effected the normal temperature of concrete walls is not complete.

The result of a late special inquiry to a number of labourers who have occupied concrete cottages for many years was that in every case " no sweating of the walls ever occurred, although no fires were used in bedrooms except in illness."

These cottages are in the south of England; in the north-western counties and Wales, where the atmosphere is more humid, it may be different.

SOUND.

It is sometimes assumed that concrete walls and suspended concrete floors are soundproof, but they are very much otherwise owing to their density, a matter of not much consequence in cottages and other buildings, but an objection in some cases. There is no practical remedy for this except to build party-walls and partitions hollow by means of 2-in. slabs tied together with galvanised iron ties and having a 2-in. cavity forming an air space between, and in suspended overhead floors by hanging metal lathing for the plastered ceilings an inch or two beneath.

XI.

CAST CONCRETE.

Cast concrete, as its name implies, is concrete poured or placed in wood or iron moulds, and includes blocks and slabs, as described in Chapter VI.

In a general way it applies to lintels, door sills and steps, posts, window sills, cattle mangers, water troughs, wall copings, and numerous other things that in country districts more especially have hitherto been made of wood or stone. The manufacture of these and ornamental and architectural products has become a special business, and, although castings of a simple character can be made on the site, it is often better, where a limited quantity is required, to purchase them direct from the manufacturers and save the cost of moulds and the possibility of failure. The great advantage is that concrete castings will not rot like wood, rust like iron, or become affected by severe climatic changes.

Either the wet or dry process can be adopted, but in a general way the wet is the most suitable, as it results in concrete which is harder and more waterproof than that made by the dry method. An excess of water with a view of obtaining smoother surfaces should be avoided. If the dry process is preferred the description in Chapter VI. applies, and any of the aggregates named in Chapter I. are suitable except clinker and chalk.

When the castings will be subject to foot wear, such as door sills and steps, the pallets and sides of the moulds corresponding therewith which will be exposed to wear or be in sight should have $\frac{3}{4}$-in. in thickness of cement and granite sand 1—2 or 1—3 applied thereto and upon which and against which the aggregate is placed, the latter being graded from 1-in. mesh down to coarse sand size and less for small castings, down to coarse sand size entirely.

LINTELS.

Fig. 6 is a plan of a wood mould for making three lintels at a time, but any number can be arranged for. The sides and ends may be 1½ in. thick or as may be necessary, and the divisions the same. The pallets or loose bottoms should fit in somewhat slack, to provide for swelling, and be strong enough to bear the weight of the lintels without deflection when removed. The mould should be held together by clamps or cleats sufficiently strong to prevent the concrete from pushing any portion out of place. If smooth soffits and face are required a thin coat of cement and sand should be applied to one side of the pallet. For lintels 4 ft. in length and 6 in. in depth two $\frac{3}{8}$-in. iron rods should be embedded in the concrete an inch from the bottom and an inch from either face, and for lintels 4 ft. to 6 ft. in length and 9 in. in depth three rods should be inserted, one midway between the two outside ones, the ends being slightly bent. No iron embedded in concrete should be painted.

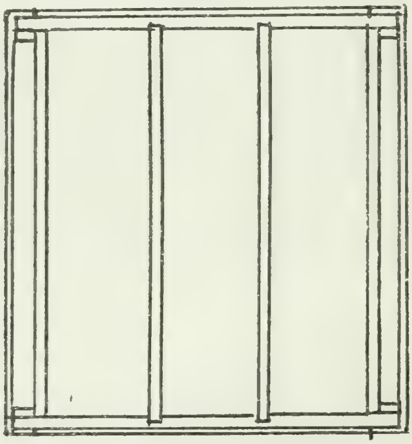


FIG. 6. LINTEL MOULD.

The rods will not be likely to slip in the concrete owing to the heavy load they have to support as the adhesion between a plain steel rod and the concrete in which it is embedded can safely be taken at 100 lb. per square inch of the surface of the steel, this being the working stress which is permissible according to the report of the R.I.B.A. Committee and the Regulations of the London County Council, and a $\frac{3}{8}$-in. rod would therefore resist a pulling strain of over 100 lb. per lineal inch.

In fixing lintels in a building it sometimes occurs that careless workmen place the soffit uppermost, whereby the entire assistance of the reinforcing rods is lost. If an iron stamp with the letters "top" is impressed in the soft cement top while the concrete is being filled in it at once discloses an error by looking up at the lintel when fixed.

WINDOW SILL.

Fig. 7 is a section of a wood window sill mould. *A* is a bearer about 3 in. × 1½ in.; one is required at each end of the proposed sill; *B*, a stop 3 in. × 1¼ in., firmly fixed to *A*; *B* on the opposite side, 4 in. × 1¼ in.; *D*, the bottom, 1½ in. thick; *E*, fixed side, 1¼ in. thick, nailed to *D*; *EE*, loose side, 1¼ in. thick; *CC*, ¾ in. linings in narrow widths nailed to block *H*, one at each end and one in the centre of the mould, to *D* and *E*. A groove for an iron tongue is made in *D* and a piece of bar iron placed in same, 1 in. × ¼ in.; *M*, folding wedges to bring the side *EE* tightly against the bottom, *D*. Use a little cement and sand about ½ in. thick to take the place of the same amount of concrete along the underside and outer edge of the sill to form a smooth, hard surface. The water groove can be formed in the cement with a piece of sheet iron cut to the shape and fixed to a gauge stick worked from the side of the mould. Wood ends can be fixed with clamps or attached with wood screws.

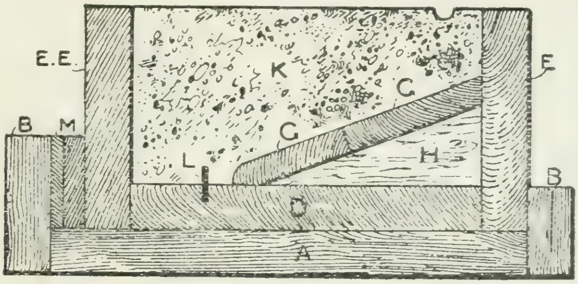


Fig. 7.

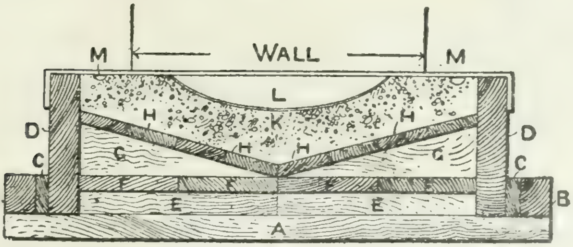


Fig. 8. Coping Mould.

When hard enough to move turn the mould carefully over, block up the ends about an inch, and provide sawdust or some material of a soft nature for the sill to drop on, and gently tap the mould with a hammer until the casting falls away. The iron tongue will be found firmly fixed in the concrete and is for the purpose of forming a water check by means of a corresponding groove in the wood window frame.

COPING MOULD.

Fig. 8 is a wood mould for a limited number of wall copings; *A*, a 3 in. × 2 in. bearer, one at each end of the mould; *BB*, side pieces nailed firmly thereto; *CC*, folding wedges; *DD*, 1¼ in. sides of the width necessary; *EE*, ledges about 4 in. × 1½ in., to which the bottom boards, *FF*, are nailed; *HH*, ¾-in. boards fixed to blocks *GG*. Wood ends can be fixed with wood clamps or screws, as previously described, and the casting released in a similar way.

IRON COPING MOULD.

Fig. 9 shows a mould for copings where a large number are required. The sides and ends are 1½ in. thick mortised and tenoned together to form a kerb without a bottom. *AAA* are the sides and ends, 1½ in. thick; *BB*, cast-iron patterns or bottoms, about ¼ in. thick, in halves and butted together in the centre; *DD*, wedges passing through mortises in the ends to keep the mould rigid; and *FF*, mortises in the ends with corresponding tenons on the sides.

At each end a sheet iron template to the exact section of the coping rests upon the iron bottoms, *BB*, and this is kept in place by wood stops screwed to the sides of *B* or in any other way that may be found convenient. As no water comes in contact with the wood the moulds will provide for almost an indefinite number of castings.

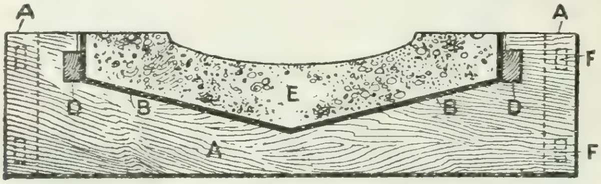
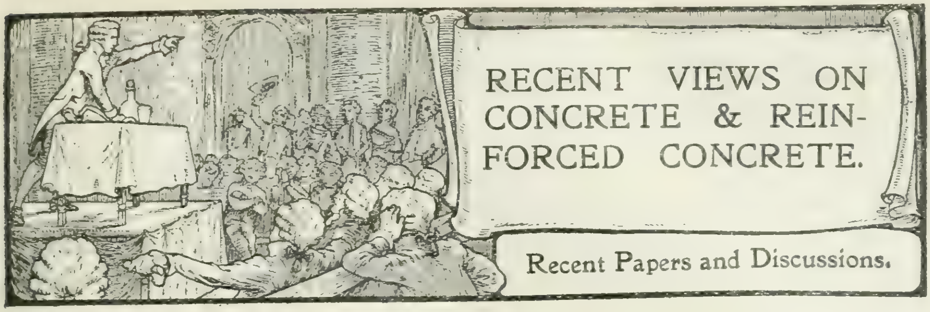


FIG 9. IRON COPING MOULD.

When the castings have been removed the moulds should be at once cleaned with a hard brush and small imperfections in the casting made good with cement. Before the skim coat or granitic bottoming is applied a thin brush over of oil and paraffin or Leeds grease should be given and time allowed for it to penetrate if a wood mould and cleaned off if iron. The concrete should be gently tamped or punned as it is being deposited in the moulds and care taken with all angles and arrises that they possess no cavities to avoid imperfections in the castings when liberated.

These illustrations and instructions, in conjunction with those contained in Chapter XII., should afford all that is necessary for making moulds for ordinary plain castings. The more practice workmen have with this class of work the more efficient, obviously, they become, and good country carpenters and the better class of country labourers take more interest in work of this kind, and in concrete generally, than ordinary town labourers, so far as my experience goes.

(To be continued.)



RECENT VIEWS ON CONCRETE & REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE CONCRETE INSTITUTE

SOME PRACTICAL POINTS IN THE DESIGN AND CONSTRUCTION OF PARTITIONS.

By H. L. BARRACLOUGH.

The following is a Paper which was read at the Concrete Institute on March 21st, together with a short account of the discussion which followed.

INTRODUCTION.

LIKE many other things, the war has brought partitions into an almost endless number of uses, one of which has been for the building of huts and houses. Though this may be new to some, the writer has been concerned in the building of schools and sanatoria, some years ago, with plaster slabs, cement rendered outside, and those places stand to-day as good as when erected.

Simple as it may seem, the erection of partition slabs, as experience has proved, should only be entrusted to the hands of men used to this particular class of work. A badly built-up job is sure to develop cracks in unthought-of places, the blame very often being fixed on the manufacturer of the particular partition slabs.

There are several kinds of partition slabs manufactured and on the markets—breeze, pumice, plaster and clay—each of which has its special claims.

PLASTER.

Plaster, until recently, has been the most common in use, and has many advantages over breeze slabs. Solid plaster slabs are light, easily fixed, with little or no waste in erection. When up they form a solid wall, hygienic in all ways, as every possible lodgment for dirt and vermin is effectually closed after the walls have been plastered out, and are fire and sound-resisting, provided the work has been executed by skilled labour, which goes largely to ease the question of after-cracks.

My opinion is that hollow plaster slabs, although lighter, have some objectionable features, the compressional strength of the slab having been somewhat destroyed through the apertures ; and further, if spiking is resorted to for fixing, very often the spikes crack the slabs when being driven in, and generally weaken the whole wall.

In fixing plaster partition slabs it is essential that the suction should be destroyed by applying a thin cement wash, and that they should be well bedded in plaster in preference to spiking.

It is preferable that all slabs used for partition work should be tongued and grooved horizontally and vertically, and in fixing the grooves should be placed upwards and the joints broken, as in brickwork, and the vertical joints carefully grouted in with plaster, both where they join up to the door frames or brick walls and where they butt against each other. Where a slab has to be cut it is advisable to form a groove by scooping a piece out.

Plaster slabs have been successfully used for external works fixed on wood framings and faced with tiles, but this is an expensive form of work, and if not carried out by experienced labour the tiles are liable to come off.

A well-known firm has recently introduced a plaster slab with a special face to receive cement rendering for external work, and they claim that it will withstand the weather for twenty years without being re-rendered. This system could be used in conjunction with light reinforced concrete piers and beams or wood framing, and has the advantage of being a very rapid construction. Doors and windows can practically be fixed in any position, as the openings can easily be cut, after the wall is up, without much danger of damaging other parts.

The foundation need only be 9 in. depth of good concrete under the wall, weathered on the outside, doing away with the necessity of any damp course.

BREEZE SLABS.

Breeze partition slabs are manufactured by several firms, in various sizes and shapes. They are light, and one on the market, to my knowledge, affords a first-class key for fixing, and is cast with an indentation with horizontal edges. There is always a danger that the breeze used in manufacturing slabs may contain sulphur, which will in time discolour the plaster and cause it to scale off ; and where the partition is faced with tiles the latter will crack and often fall off, from the action of the sulphur, which seems to go on for a long time, thus causing much annoyance and anxiety, and where used it is advisable that the slabs should be obtained only from a firm of sound repute.

PUMICE.

The pumice slab is a very light form of construction, convenient to handle, and is manufactured from pumice and volcanic sand (imported into this country from Italy) mixed with Portland cement. These slabs form a rigid construction when up. Nails can readily be driven into them and take a good hold, doing away with the necessity of plugging for fixing skirtings or picture rails.

HOLLOW TERRA-COTTA.

The hollow terra-cotta partition tile is well known to many, and can be obtained in different sizes from several firms, and has the advantage of being easily handled. It can be obtained with a keyed or smooth face, and is being used just now extensively for exterior work. It is easily built up, the horizontal joints being bedded with cement, and the vertical joints grouted up, and seems to be quite effective in withstanding the weather, but it has only come into prominent use for this purpose recently, owing to the present shortage of other materials, and it remains to be proved what effect time will have on it. I am, however, strongly of the opinion that there are several points in its favour for this purpose, being cheaper than a brick wall of the same thickness, resists the damp better and ensures a more even temperature, but does not lend itself to nailing. Where it is necessary to fix skirtings and rails, provision should be made for same at the time of erection by carefully inserting plugs in the joints. Should this not be done at the time of erection, and it is found necessary to fix electric fittings or hook rails, the joints should be cut out, and a plug built in, as any attempt to drive a nail into the tile is generally a failure, besides being liable to break the face of the whole tile.

CRACKS IN PARTITIONS.

Those of us who have had to do with partitions know only too well that they mostly have the annoying habit of showing cracks which more often than not go right through. These cracks may develop from either of the following causes :—

The cracks generally occur just under the ceiling or near walls and door frames, or at top corners of door frames. The cracks at the tops or by the walls may be caused by variation of temperature, causing expansion or contraction, or through the supports deflecting or settling. Cracks also are generally to be found on top storeys of buildings with large flat roofs, owing to the expansion of the flat as well as the partition, and up to the present I have not seen any successful method of stopping this occurring with a built-up partition, for even when cut and carefully filled in the cracks will readily appear again.

The cracks on doors are particularly noticable when the jambs project a few inches above the frame, and this is caused by the wood frame swelling, through absorbing the moisture from the partition whilst it is being erected. These can generally be stopped up successfully if cut out and filled in, after the partition has had time to dry out, and will not appear again, provided the door frames are fixed rigidly enough to prevent the partition from being shaken when the door is shut quickly. The best remedy, however, is to prevent this by stopping the door jambs off flush and carrying the partition over in one slab.

POSITION OF PARTITIONS.

The position of a partition is too often left to be settled after the floor and beams are all in, and then it is placed anywhere, whether the weight is supported by a main beam or only by the floor, and more often than not gets placed on the floor, away from the main beam, which may only be calculated to carry a load of 100 lb. per foot super ; whereas many 3 in. partitions, when plastered both sides, weigh 18 lb. per foot super and 10 ft. is quite an ordinary height for such a partition ; therefore 1 ft. run would weigh 180 lb. The heaviest articles of furniture in domestic buildings are generally placed against the partition, and in an office it is quite an ordinary occurrence to find a heavy safe one side and a tier of shelves filled with books and papers on the other. Taking the total weight of the safe at 15 cwt., placed in the centre of the bearing, and the bookcase at 2 cwt. per foot run, we find, if a 3 in. partition, 12 wide × 10 ft. high, happens to be placed on the floor we get the following load per foot super in that particular place :—

3 in. partition—18 lb. per ft. super × 12 ft. wide × 10 ft. high = a distributed load of	2,160 lbs.
1 safe = a distributed load of 30 cwt. = ...	3,360 lbs.
1 tier of shelves 10 ft. wide at 2 cwt. per ft. run = 20 cwt. = ..	2,240 lbs.
Giving a total load of	7,760 lbs.

Taking the width of floor occupied as 3 ft. × 12 ft = 36 ft. super.

Therefore 7,760 lb. ÷ 36 = 215·5 lb. per foot super on this particular portion of the floor, which is more than double what the floor weight and main beams were calculated to carry, and, except for the large safety factor required by the authorities, there would be more than mere cracks appearing. The writer is strongly of the opinion that the position of all partitions wherever possible should be settled at the time of planning, and proper beams arranged to carry them and when this cannot be done it is advisable wherever possible to have partitions cast *in situ* and reinforced with small steel rods, forming a beam from wall to wall.

PARTITIONS WITHOUT SLABS.

There is yet another means by which a partition can be constructed without slabs, and where a very thin partition is required ; it has many advantages, as when finished and the whole thoroughly set it forms a very strong and rigid structure, being light, occupying little space, and being practically sound, fire and vermin-resisting. There is no temporary sheeting or strutting required, and the work can be done with little labour.

The foundation work usually consists of vertical rods, securely and tautly fastened at top and bottom by screws, nails, or clamps at about 12 in. centres. To these supports expanded metal lathing is firmly secured by soft wire or some other convenient means, and both sides covered by any quick and hard-setting plasters, which can be finished to a smooth face without loss of time.

The solid partitions are sometimes built only 1½ in. thick, but generally made to finish 2 in. thick, and can be used in combination with any class of concrete floors and ceilings or ordinary wooden floors. Doors and other openings that may be required for lifts or ventilation can easily be formed and frames securely fixed in position at the time of construction or after the partition is up. The whole forms a partition possessing all the desired advantages of a divisional wall not required to carry any weight, and occupies the least possible space for such purposes. This class of partition is very suitable for internal lift wells, where good anchorage can be obtained for the vertical tie rods, as it takes up little room and stands vibration.

CONCLUSION.

These are only a few of the many classes of fire-resisting partitions, but I have endeavoured to include those most generally used.

As mentioned previously, one of the most troublesome things in connection with partitions is their habit of cracking.

I hope, however, that some useful information regarding a cure for the complaint may be brought out in discussion, as no doubt partitions will play an even larger part in future constructions of small property than they have done in the past.

DISCUSSION.

The President, in opening the discussion, remarked that partitions would play a very important part in future construction. In old days timber was so conveniently procured that very few took the trouble of thinking about anything else, but the war had brought the use of timber substitutes in the way of walls and partitions into great prominence.

Mr. E. Fiander Etchells said there was no doubt partition work was going to play a very large part in future construction. The earliest Building Acts of London required walls about 3 ft. thick as a minimum. These requirements had been relaxed from time to time. In 1894 they had walls of 18, 13½ and 9 in. with 4½. Now and again in brickwork the partitions inside hardly counted as walls. In the General Powers Act steel frame construction they had walls 13½ and 9 ; in the Reinforced Concrete Regulations they had walls down to 4 in. in thickness, so there had been a gradual reduction in wall thickness, and that had been accompanied by a change in the nature of construction. Earlier constructions were homogeneous in type, there was no discrimination between pier and panel, but with the gradual development of frame construction, skeleton construction, in which the greatest proportion of the load was being borne by beams and pillars, there had been a gradual reduction of panel thickness. There had always been an incentive towards economy, so that hundreds of buildings were approved of now that would not have been constructed before the war. The walls must generally have 3 in. partitions with about ¾ in. rendering on the outside and ¼ in. on the inside, making a total thickness of 4 in. That, at any rate, was what was shown on the plans ; in practice the ¾ in. rendering might not be quite ¾ in. and the ¼ in. inside might not be of that size when measured with the micrometer. One cause of cracking was very frequently the load of an internal partition not being allowed for at all. Any of them who had to deal with slab partitions ought to hand them over to some practical man, but he counselled supervision to see what assumptions were made on weights and pressures.

Mr. E. McLean Gibson's experience was that plaster needed a roof over it during building. Slabs were usually of sufficient weight and size that they could be handled by one man. Those shown by Mr. Barraclough looked 5 or 6 ft. long by 3 in. wide. Were not many of them broken in handling ? In his experience plastering outside and in was very expensive, especially if the building was only to be used temporarily. The 12 by 12 terra-cotta block was largely used for outside work and inside partitions for lavatories and general ablution places. The sand cement block about 2½ in. thick 18 by 9 was generally fairly straight. It was grooved all round, and when bedded in Portland cement and properly pointed it made quite a clean wall outside and in. But already they had found trouble with the sand lime blocks having free lime in them.

The President, in conveying the thanks of the Institute to Mr. Barraclough for his paper, asked what a plaster partition was made of. He also wished to know what precautions were necessary in the manufacture of breeze concrete slabs. He had used them with some success, but he had always been rather nervous of them, knowing that breeze concrete was liable to be treacherous, as breeze and Portland cement did not seem to agree very well. It struck him that it would be quite possible, though he had never seen it done, to make a thoroughly good partition which would not settle down by reinforcing with light wire or steel rods, but still to have slab partitions. He did not see why it should not be possible to introduce light steel wires into the horizontal joints of a slab partition, and by so doing and possibly by bending it well into the piers make a partition in which there would be no danger whatever of settlement, even though the floor or foundation on which it was resting was weak It ought to be possible to introduce some material made with Portland cement, and therefore of great durability, having weather and fire-resisting properties, which could be penetrated by nails and so on, without destroying the block.

THE LECTURER'S REPLY.

Mr. Barraclough, in reply, believed there was a block on the market for which a claim was made that it could be nailed, but he had no experience of it. He had had a sample, but it soaked up water like a piece of blotting paper. It was necessary that plaster partition slabs should be kept from the damp. As regarded the centres of the piers, he did not advocate more than 13 ft. He had been very unlucky in his experience of breeze slabs ; they gave a great deal of trouble. Large firms who went in for that particular class of work had now learned to take precautions to see that their stuff was clean. If they got clean breeze, as they used to in days gone by, it was fairly safe. The sand lime block was manufactured by one or two firms, but he did not know the secret of it.

CORRESPONDENCE.

CONCRETE SIMPLIFIED.

To the Editor, CONCRETE AND CONSTRUCTIONAL ENGINEERING.

SIR,—Referring to Mr. Marriott's letter in the April number my reply thereto is that the applicability of the various aggregates described in the February number related mainly to walls from six to twelve inches in thickness, but, obviously, to concrete for other purposes as well.

Slag.—With regard to slag I said that it should be aerated, and, after being graded, washed to eliminate the sulphur, and that this applied to coal residues also. My remarks were to the effect that by so doing there was insufficient sulphur left to be injurious ; at any rate, I always found this to be the case. The enclosed photograph is of a building, the walls of which are entirely of slag concrete, erected forty-seven years since, and which have never developed any faults ; and this applies to other buildings and purposes for which slag was used at the same time and subsequent thereto.

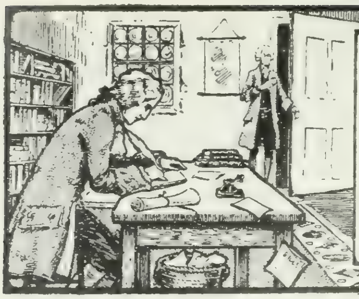
Breeze.—An inquiry, some years since, as to whether a large amount of coke-breeze flooring had shown or given any signs of expansion, elicited a reply that : " The floors, many of which were a hundred feet in length, with no division walls bearing on same, had shown no signs of expansion—although erected over four years (at that time)—and were satisfactory in every way. If any expansion had taken place it must have affected the walls, but there was no evidence in this direction." Similar replies were received in connection with other floors.

Boiler Ashes.—About twenty years since some floors and stairs—at Southampton, I think—were made with locomotive ashes concrete and completely failed. An inquiry as to the cause resulted in the discovery that the railway company gave their drivers gratuities for lessening coal consumption, and to effect which the drivers added fragments of stone to the coals, when obtainable, in passing through lias limestone districts, and which did not slake until water was added for concrete purposes, and for some days after. In an application for locomotive ashes a few years since which the Somerset and Dorset Railway Company had for disposal, it was asked whether they would be guaranteed free of lias stone fragments and the reply was that they were unable to do so. This is not an exceptional case. As I stated in my introduction to these articles, I am only giving my experience, and the results arising therefrom, of a definite nature, and which can only be ascertained after a sufficient interval of time has elapsed after concrete has been employed. Experiences differ, even where materials and methods are identical, and in some failures I suggest it is a question whether they have arisen from the accepted cause, or from some others which were not discovered.

Yours truly,

THOMAS POTTER.

NOTE.—We have received other communications regarding the above articles, which we are compelled to hold over until our next issue.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Planing Machines of Concrete.—*The Iron Age*, New York, states that two gigantic metal planing machines, the principal parts of which will be of monolithic reinforced concrete construction, this including the beds, housing of plattens, with cast-iron for bearing surfaces, are being built by the Amalgamated Machinery Corporation, Chicago. The work of the machines is the planing of beds for long gun-boring machines. The concrete beds of the planes are 184 ft. in length; the plattens are 90 ft. long and 13 in. thick. The width between housings is 72 in., and the cross-rail, which is stationary and faced with cast-iron, is 4 ft. square. They will plane 36 in. down to 20 in.

Ministry of Munitions of War (Machine Tool Department).—In pursuance of the instructions of the Controller of Machine Tools, dated February 19th, 1918, Reference H.H.B./G.S., the undertaking to be signed by, or on behalf of, dealers in Engineers' and Machinists' Imported Small Tools is now cancelled.

The Ministry of Munitions has, however, imposed the following regulations with regard to priority classification in respect of all Small Tools, whether imported or of British manufacture:

No firm or person is permitted to issue a Class "A" Certificate with an order for small tools unless

(*a*) Such Small Tools form a component part of a direct Government Contract, or

(*b*) Specially authorised in writing to do so by the Priority Department of the Ministry of Munitions.

Any applications for such higher priority must be made through the Director of Small Tools, Charing Cross Buildings, Embankment, W.C. 2.

Any Class "A" Certificate issued must bear the Contract Number in the case of (*a*) and the Priority Permit Number and Classification in the case of (*b*).

Firms holding a P.5 maintenance permit are authorised to quote their maintenance permit number and Priority Classification on orders for Small Tools up to the value allowed under the terms of their maintenance Permit.

All other firms and persons placing orders for Small Tools required for the upkeep of existing industrial plant should issue a Class "B" Certificate with their order.

Orders for Small Tools without certificates may only be accepted when such orders can be executed from stock and without prejudice to orders received with Classification Certificates as above.

Regular dealers ordering Small Tools for stock may issue a Class "B" Certificate with their order, but if they do they must only dispose of such Small Tools in accordance with the regulations set forth on the back of the Certificate. They should, however, note that *bona-fide* munition workers, or soldiers engaged on mechanical work who desire to purchase Small Tools in connection with such work may properly sign Class "B" Certificates provided that they state thereon the names of their employers or the units to which they belong.

It will be noted that dealers desiring to obtain Small Tools for sale to the general public without certificates can only obtain same by placing an order without a certificate, and such order will only receive attention when the supplier is in a position to give delivery from stock without prejudice to orders received with classification certificates.

It will be noted that the above regulations do not permit the issue of a Class "A" Certificate for Small Tools which are required for the manufacture of goods ordered on a direct Government Contract—*e.g.*, a firm having a direct Contract from the Ministry of Munitions for the manufacture of guns may issue a Class "A" Certificate bearing the appropriate Priority Classification attached to the Contract for any of the material used in the manufacture of the guns, but such a firm can only issue a "Class B" Certificate for the Small Tools to be used in the manufacture of the guns.

The Forms of Priority Classification Certificates referred to (sometimes known as Munitions Certificates) can be obtained from all the principal Post Offices.

A Concrete Monument 350 ft. high.—The *Concrete Age* reports that a 350-ft. monument is being erected entirely in concrete at Fairview, Kentucky, in honour of Jefferson Davis. Most of the materials used are Kentucky products, and the sand is manufactured from natural rock.

The construction consists of a monolithic concrete shaft. At the base the walls are 9 ft. 6 in., tapering to 2 ft. 4 in. at a point 315 ft. from the ground. The apex or cap is 35 ft. high, this top section being reinforced concrete. Under the base solid rock was blasted out for a depth of 10 ft. with a solid core of poured cement run in to form a solid foundation, the whole being blasted out close to the line—forming a solid binder, which dries hard and firm. Layer after layer of large rocks and concrete are worked into the walls.

The facing is of poured white cement with limestone sand, in a 1 : 2 waterproof mix. The facing is poured along with the walls, a template being slipped in between the inner surface of the form and the facing poured. When the wall is poured and tamped the template is slipped out, and the facing and wall set firmly together while they are both wet.

Hydraulic steel-pressed forms are used on the exterior and wooden forms on the interior of the shaft, a series of 8-ft. forms being used inside and out and moved up as the lower forms dry out.

At the base the outside measurement is 35 ft. each way, while the inside measurement is 19 ft. 6 in. The outside dimension at the top is 23 ft. to 24 ft. where the walls end, and the top section begins at 315 ft. from the ground. The inside dimension is 18 ft.

The base of this big monument is formed of concrete made from crushed granite, which will take a polish, whereas limestone will not. The concrete in the walls throughout is made of a 1 : 2 : 4 mix, the sand being of ¼ in. or under crushed rock, while the rock used is 1½ in. or under. One- and two-man stones which are worked into the walls all the way up weigh from 50 lb. to 200 lb. each. These stones are set in the centre of the wall while the concrete is poured around them.

Inside the monument there will be a steel stairway extending from floor to floor, these floors being of reinforced 8-in. concrete.

This monument is being erected on the farm that was the birthplace of the former President of the Confederacy, and the unveiling will take place in June.

Apart from its historical importance and its size, this monument represents something entirely new in engineering circles as the first large monument erected in concrete.

Concrete Roadways in Shop Yards.—In order to facilitate the handling of material and supplies in the shop yards of the Atchison Topeka and Santa Fe, at Topeka, the company has laid down about 2½ miles of concrete roadways connecting all the principal shop buildings, warehouses, goods sheds, timber yards, car sheds, and unloading and storage platforms within the shop enclosure. The roads are of one-course concrete construction throughout, 6 in. in thickness at the edges, with a slight crown (about ½ in.) in the centre, which varies with the width. The level crossings are constructed with 12 in. of concrete under the sleepers, upon which is placed a sand cushion. On account of the small wheels of the trucks and trailers used in

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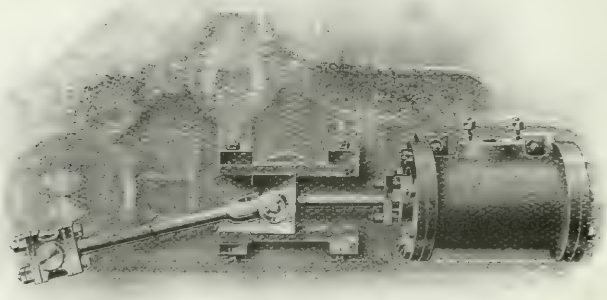


Illustration shows the engines of a 7¼″ × 10″ standard Zenith Winch. Piston and connecting rods are mild steel forgings machined all over and brass bushed throughout. Internal lubrication to crosshead, all parts easy of access. These are only a few of the features of Zenith Winches Our catalogue on these winches is only being sent to those who write for it. Get your copy now

DOCK HOUSE, Billiter Street, LONDON, E.C.

hauling material at the shops, it was desirable to have a small flangeway between the rails and the roadway in order to lessen as much as possible the jar incident to crossing, so the flangeways are on the average $1\frac{3}{4}$ in. wide. On the main line crossings they are made by using angle irons of $\frac{3}{8}$-in. by $2\frac{1}{2}$-in. by $2\frac{1}{2}$-in. section, the bottom leg resting on the concrete blocking and the outer edge against the web of the rail. The angle bar is drifted to the sleepers by bolts driven through holes drilled in the lower leg. On siding crossings the construction is wholly of concrete. After the angle irons for the flangeways have been anchored the concrete is run to a surface even with the top of the rails. Angle irons also are embedded in the concrete on the sides and the termini of the roads at places where the concrete is liable to be injured by constant trucking to and from shop buildings.

Expansion joints are placed every 30 ft. Between these are placed two strips of tarred paper, held in place by steel plates, which were removed when the concrete had been placed 10 ft. in advance of the joint. The 12-ft. roads are reinforced with $\frac{3}{4}$-in. rods placed along each side and running the entire length of the roads, and $\frac{3}{4}$-in. bars placed crosswise every 30 ft., or at the ends of each expansion joint. The roads 10 ft. or less in width are not reinforced. Standard Portland cement of the American Society of Testing Materials was used in the work, the fine aggregate being clear sharp river sand and the coarse aggregate consisting of clean crusher-run Garnett stone of $1\frac{1}{2}$-in. maximum size from which all the fine screenings had been removed. In mixing the concrete the time was $1\frac{1}{2}$ min., and the concrete was delivered direct from the mixing machine to the roadway and levelled.

Before the concrete set a common painter's brush was used to give the top of the road a smooth surface, or where rough spots existed a wooden float was used to smooth it out. The finished roadway was then covered with earth and water for curing and left covered in this manner for 21 days.

The roads have been in service for several months and are giving satisfactory service. They are made use of by electric trucks and trailers, hand trucks, horse-drawn vehicles, automobile trucks and trailers and by pedestrians, and are the principal factor in the economical distribution of materials to the various shops and storage yards.

The concrete highways serve as and are instrumental in securing better fire protection, as they permit of the more rapid handling of fire apparatus. In permitting the maximum use of mechanical means of transportation facilities in the store and shop grounds they are of special interest owing to the present difficulty of securing labour.

In connection with these roads the Santa Fe has also paved a large area between the machine shops, blacksmith shop, power house and oil house over which much trucking is done. Over 6,410 sq. yd. of concrete pavement was installed here, and 1,275 sq. yd. under railroad crossings. The construction here is similar to the roads. It gives ideal storage facilities, permitting proper drainage, and is independent of weather conditions.

Residential Flats of Reinforced Concrete.—A recent serious fire at Christchurch, New Zealand, destroyed a block of buildings containing offices and a vaudeville theatre belonging to an important threatre-owning syndicate. The buildings also contained a large organ, insured for £4,000. It is intended to rebuild the theatre at once and on the most up-to-date lines, and later to replace the organ. The *Evening Post*, Wellington, has given particulars of proposed new buildings in Wellington, which include a fever hospital and residential flats. The former building will cost £25,000 and will have six wards, with accommodation for fifty-nine patients. The flats will be of reinforced concrete, comprising twenty self-contained residences. The building will be fireproof, and an automatic lift and a roof garden will be among the features of the building. Commenting on the latter project, H.M. Trade Commissioner writes that, while this system of housing has been tried in other parts of the Dominion, the Wellington City authorities have not previously looked upon proposals of this kind with favour. Owing, however, to the limitation of building area in Wellington, it seems almost certain that the erection of residential flats will in the future become even more necessary.—*The Architect.*

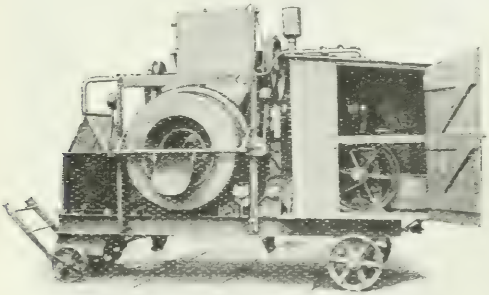
TRADE NOTES.

Housing for the Workers.—Excellent suggestions for the erection of suitable houses for the poor are made in a memorandum just issued by the Government for the use of local authorities. The provision of such houses may rest largely with the local authorities, and therefore when embarking upon a housing scheme it is to be hoped that they will take into full consideration two essentials, (1) economy in construction, and (2) the attainment of the best results for the expenditure incurred.

Generally work on the lines recommended in the recently published Government memorandum would be eminently satisfactory, but there are one or two details that could be improved upon. For instance, in regard to floors, it is stated that " a layer of bituminous composition beneath the boards is desirable," but far better results could be secured by other means. Bituminous composition is expensive and just now very scarce, but a cement of waterproofing powder will effectually answer the same purpose. A 1-in. rendering in one coat of Pudloed cement is a sure preventive against rising dampness and necessitates a much smaller outlay than the use of bituminous composition.

Metallic Liquids for Strengthening and Hardening Concrete.—We are informed by Messrs. George Lillington & Co., Ltd., specialists for waterproofing wood, stone, and brick, that owing to their rapidly increasing business, they have removed from 124 Holborn to large and commodious new showrooms at 40 Holborn Viaduct, E.C., and that they propose shortly holding there an exhibition of their productions in order that their many uses may be practically demonstrated.

Messrs. George Lillington & Co., Ltd., specialise in metallic liquids for strengthening and hardening concrete, fireproofing every kind of material and iron and steel preservation.



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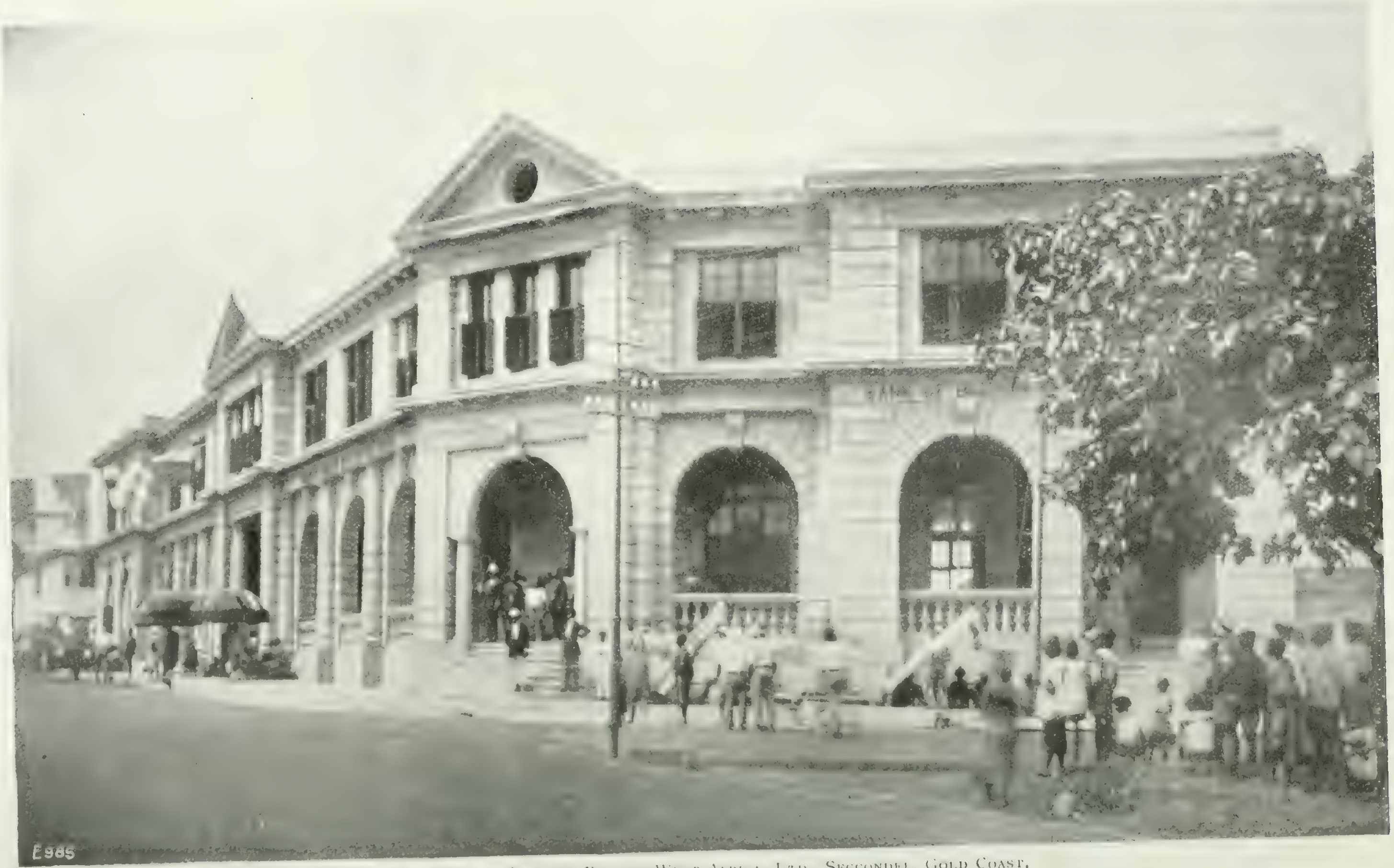


Premises of the Bank of British West Africa, Ltd., Seccondee, Gold Coast, showing State Umbrellas of Native Chiefs.

(For Description see page 285.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIII. No. 6. LONDON, JUNE, 1918.

EDITORIAL NOTES.

THE CONCRETE INSTITUTE.—ANNUAL MEETING.

THE recent annual meeting of the Concrete Institute with the presentation of its annual report practically brings with it the conclusion of Mr. Wentworth Sheilds's tenure of office as president.

We take the opportunity of congratulating Mr. Wentworth-Sheilds upon the fact that the Institute has been able to hold its own during his term of office, regardless of the vicissitudes of the war and other difficult circumstances, and, above all, that it was during his term of office that the Concrete Institute was able to commence a piece of true research work, for it was largely due to the outgoing president that this research work was started and a suitable organisation inaugurated to deal with it.

RESEARCH.

The necessity that such research work in respect of concrete should be started was already felt as far back as 1907, when the British Fire Prevention Committee, prior to the formation of the Concrete Institute, had a Special Commission dealing with certain problems relating to concrete aggregates, of which the late Sir William Preece, F.R.S., was chairman, and Mr. Edwin O. Sachs, F.R.S.Ed., was deputy chairman, and in which a number of members of the technical professions were actively interested.

That Commission formulated some outline specifications and indicated what it thought was advisable in the matter of research, a detailed plan of necessary tests being prepared. But it is well known that research work requires money and in those days research of this kind did not meet with that encouragement from the home authorities which made the investigation feasible. The Commission had to be satisfied with an interim report outlining the specifications named, which have been freely used, and indicating the tests desired which have been applied from time to time where small enquiries have been on foot.

A full decade has thus elapsed until the Concrete Institute was able to take up this matter of concrete aggregates generally, and it is largely due to Mr. Wentworth-Sheilds that the investigations have at last been started and have obtained the necessary financial support and are making progress as far as the exigencies of the war permit. The inauguration of these tests by the Concrete Institute is a landmark in its history of no mean importance.

TIMBER SUBSTITUTES.

As far as other work referred to in the Institute's annual report is concerned, it has been largely that of routine, but the Institute has been fortunate in its invitations to lectures and its list of papers has been excellent. In another direction the annual report indicates that the Institute has been preparing a list of the uses of concrete for everyday purposes where it may serve as a substitute for timber and similar materials that are difficult to obtain during the war. This is a step in the right direction towards the popularisation of concrete in the interests of national economy, but we are afraid the Institute's efforts have materialised somewhat late in the day; 1916 was the year when its endeavours should have been brought to a head and energetically advanced. It would have saved the country a great deal of money and a great deal of the timber unnecessarily employed where concrete would have been the most useful and economical substitute. Now that the Institute has got so far as to prepare lists, it should shortly also issue these with some reasoned statement, in a manner that might be popularly utilised by all the many local authorities and building employers who are anxious to economise timber throughout the war and have many minor building operations on their hands.

NEW PRESIDENT.

It is with pleasure that we observe that Mr. H. D. Searles-Wood, F.R.I.B.A., has now been elected to the presidential chair at the conclusion of Mr. Wentworth-Sheilds's two years term of office. Mr. Searles-Wood has given the Institute much of his time and experience and his services as president have that particular advantage for the Institute that he has had several years of successful and active association with many of the learned societies and special professional committees, so that he can bring his administrative and varied experience to bear upon the Institute, which still requires a considerable amount of active assistance of this kind to bring it to that position which the vast developments of concrete and reinforced concrete claim at the present time. Mr. Searles-Wood's presidency also has this particular advantage, that he holds a prominent position in several of the professional societies directly and indirectly concerned with concrete and reinforced concrete and no man could better obtain the co-operation of other bodies than he can from his intimate connection with the various institutions affected. His term of office should thus also bid fair to give the Institute a most useful year.

CONCRETE SILOS.

The Food Production Department is to be congratulated on having gone outside the usual limits of official publications by presenting in a thoroughly practical form particulars as to the construction of silos for the storage of silage crops in rural districts. The small pamphlet gives among others a very useful silo which can be erected most economically with local materials in reinforced concrete. The pamphlet has reached us too late to enable us to deal with it fully in this issue, but the full particulars will be presented in our next issue. In the meantime readers interested should apply for copies to the Food Production Department, 72, Victoria Street, S.W. 1.

Segregation Area, showing Government Police Commissioner's Bungalow, Koforidua, Gold Coast Colony.

SOME NOTES ON BUILDING IN WEST AFRICA: WITH SPECIAL REFERENCE TO THE USE OF CONCRETE

By H. G. HOLT, A.R.I.B.A.

Part I.

The following description and illustrations regarding building conditions and buildings in West Africa will, no doubt, interest our readers. As will be seen from the second article, which we propose publishing next month, Portland cement plays an important rôle among the building materials imported into West Africa, and our illustrations in this and the succeeding article show some typical concrete structures erected.—ED.

At the outset I wish to make it quite clear that I do not pose as an authority on West African matters. I have not yet even paid a visit to West Africa, but it has been my privilege to have been associated, for some little time, with men who have lived no inconsiderable period of their lives in what is, or used to be, known as the "white man's grave," and who are still, nevertheless, hale and hearty and energetic business men. I trust that the following brief notes which are gathered from reliable and first-hand sources of information will be of interest and service to contractors and others interested in concrete work who are not familiar with some of the special conditions to be met in West African building operations.

The countries comprising West Africa include in coastwise order the following: Senegal (French), Gambia (British), French Guinea, Sierra Leone (British), Liberia (Republic), Ivory Coast (French), Gold Coast (British), Togoland (German, at present administered by British and French Governments), Dahomey (French), Nigeria (British), Cameroons (British and French).

A wide range of territory is therefore covered, and, naturally, climatic and other conditions vary considerably in different localities.

On the sea coast the air is very humid and salty all the year round, whereas in Northern Nigeria and in the interior generally during the dry season the atmosphere is so dry that timber shrinks and twists to an extraordinary degree; the heat is intense and the sandstorms which blow across the towns are a great nuisance and sometimes a danger. The "Harmattan," a dry wind, blows south from the Sahara desert, usually bringing fine sand with it, up to the shore and sometimes out to sea. The wind usually blows from one particular quarter on the coast in the various localities, and it is an essential part of the planning and arranging of buildings to catch the maximum amount of this breeze. This is considered of greater importance than aspect in this country.

LOCAL BUILDINGS AND MATERIALS.

Native buildings consist chiefly of mud houses of puddled clay, sun-dried bricks, bamboo, timber, etc. The clay mixture is known locally as "swish," and the walls of a mud house or "gidda" are generally built slightly on the batter. Roofs are generally thatched, but corrugated iron is now in more general use. In the northern part of Nigeria a well-built gidda is said to be cool in summer and warm during the cold nights which are experienced there. Kano, a large and important Arab town in Nigeria, some seventy miles south of the Sahara Desert, is largely built of mud or swish. This applies to most of the native townships, although the more advanced places near the sea coast contain many substantial buildings erected and owned by natives.

EUROPEAN BUILDINGS.

In the past, European buildings were chiefly built of corrugated iron sheets or steel and timber framing. Many bungalows were erected, raised from the ground on posts and weather-boarded or sheeted with iron. Timber buildings have, however, proved very costly in upkeep and unsuitable to the climate; white ants play havoc with them, and altogether they must be written a failure as permanent structures.

The thing which surprises anyone in the building trade having no previous knowledge of West Africa is the substantial character of the modern European buildings, erected chiefly within the last ten or fifteen years. It is no exaggeration to say that this is due solely to the fact that concrete building, reinforced concrete proper, mass concrete, and, to a perhaps greater extent, concrete block work, have been utilised to a very great degree. The reason for this is that suitable local building materials are not obtainable, with few exceptions. Stone suitable for building is not easily got, and there are few quarries as we know them here. In some places stone is got by blasting and rubble masonry walls are erected.

There are to be found, however, quite a number of stones suitable for building and engineering work, including limestone, and even white marble in the Gold Coast Colony, but they are not developed at all at present on anything like a commercial basis. At Abeokuta, in Nigeria, is the Aro quarry, which is one of the three quarries from which stone for the Lagos harbour works is obtained. At Lagos a coarse sand is to be had excellent for concrete block manufacture. Bricks are made by the Public Works Department near Lagos and also by native brickmakers, but they are only common bricks suitable for foundations and internal walls.

The chief native timbers are African mahogany, and Odum or Iroko wood; the latter is akin to teak. It stands the climate well. European pitch pine also stands well, and it does not appear to be much affected by ants and other insects on account of the resin.

NATIVE LABOUR.

Europeans are wholly dependent upon native labour in the construction of buildings, and, indeed, all other matters for which hand labour is required. Close European supervision is absolutely essential, and evidently the greatest patience, firmness, and tact are needed by those who spend their lives "bearing the white man's burden" in connection with the building trade in West

Africa. Every credit must be given to those men who have thus borne the heat and burden of the day in instructing the native in the art of building, and taken a leading part in the civilising of this, until recently, little known and little regarded collection of colonies. They are Empire-builders in the truest sense. Natives are very childlike, and I have heard of a concrete-mixer, if not watched, using 3 or 4 of cement to 1 of sand, because it looked prettier, or omitting the cement altogether if the casks immediately at hand were empty. Naturally the chief buildings in the British Colonies are those of a public character, such as the residences of the Governors and other officials, post offices, public offices, and other Government buildings, but these by no means complete the list. Many of the trading firms engaged in business in various places have erected solid and substantial buildings in which their business is carried on by the European and native staffs. Among these, in West Africa, may be mentioned Elder, Dempster & Co., Ltd., Millers, Ltd., and Swanzy, Ltd. One of the pioneer institutions which has taken a leading part in the development of a good type of building, suitable for the conditions of climate and the nature of the business carried on, is the Bank of British West Africa, Ltd., which has branches in all the leading towns throughout not only British West Africa, but also in Liberia, the French Ivory Coast, Sta. Isabel, Fernando Po (Spanish), and they have also established a branch at Lome, Togoland, where a German concrete-built building now houses the British Bank. The illustrations accompanying this article, which are reproduced by the courtesy of the Bank of British West Africa, Ltd., are eloquent of the good work which has been done during the last ten years.

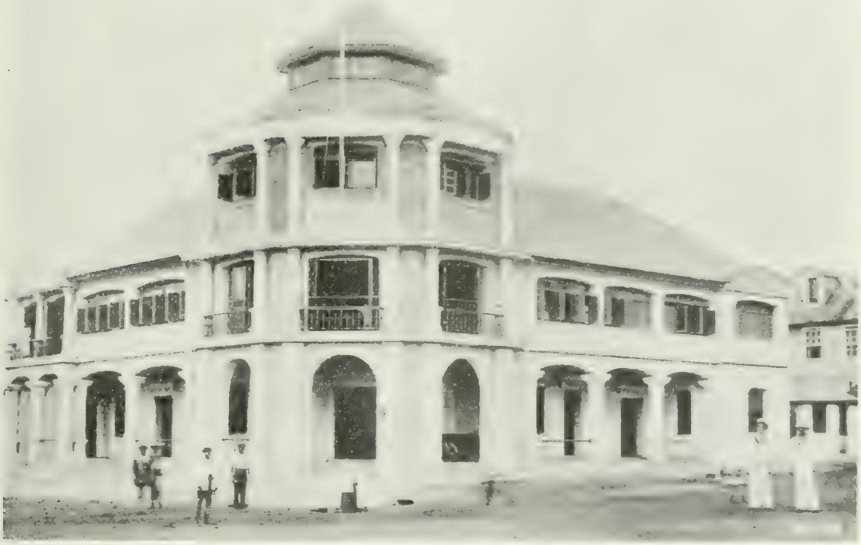


FIG. 1. FRONT ENTRANCE TO BANK BUILDING AT FREETOWN, SIERRA LEONE.

These buildings comprise bank offices, warehouses, and residences for the staff of the bank in the various localities.

A brief description of the buildings illustrated will no doubt be of interest and the gradual development in the style of building will be noted.

At Freetown, Sierra Leone, the foundation stone of the bank building, shown in *Fig.* 1, was laid in January 1909, and the building was completed and opened for business in 1910. It was designed by Mr. J. H. Garner, Building Superintendent of the Bank of British West Africa, Ltd.; a further illustration (*Fig.* 2) shows the side of the building with the concrete boundary wall enclosing the tennis court, which is of cement, and has recently been added under the supervision of Mr. J. Canning, Assistant Building Superintendent to the Bank.

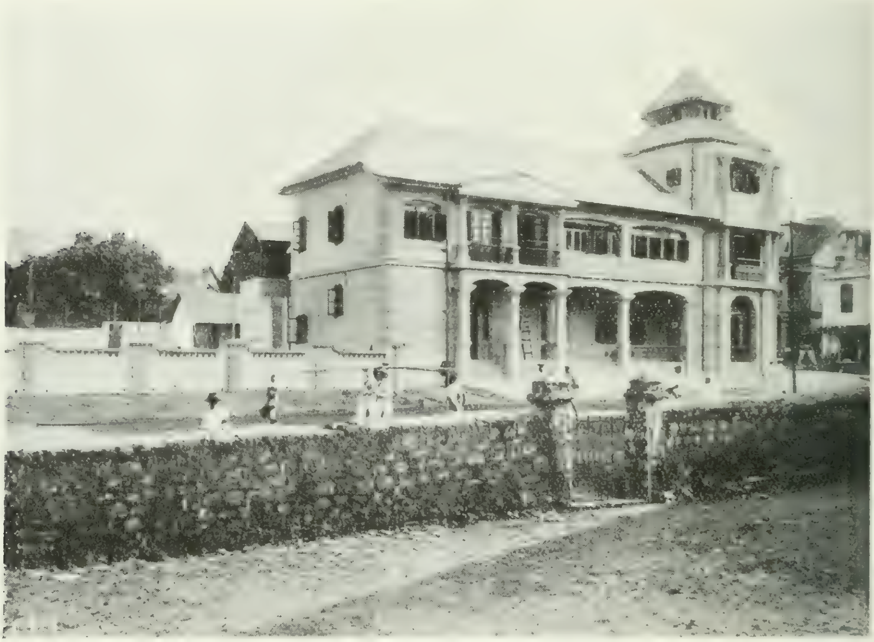


Fig. 2. A Bank Building at Freetown, Sierra Leone, showing Concrete Boundary Wall enclosing Concrete Tennis Court

The building at Monrovia, the capital of Liberia, now an allied State, shown in *Fig.* 3, comprises banking office with island strong room, manager's, accountant's, and clerks' offices; the bank has a verandah on two sides, as shown by the photograph, and it was built on a steeply sloping site, the main portions of the skeleton structure consisted of steel joists, and concrete was used for the walling blocks, ground floor, etc. The first floor affords accommodation for the manager, his suite of rooms or flat consisting of dining room, lounge, two bedrooms (with sitting verandahs), bath room, E.C., and warehouse. On the second floor the remainder of the European staff occupies a flat which gives a dining room, lounge, three bedrooms (with sitting verandahs), two bathrooms, and E.C. A kitchen and room for native boys and warehouse are provided in the compound. Considerable

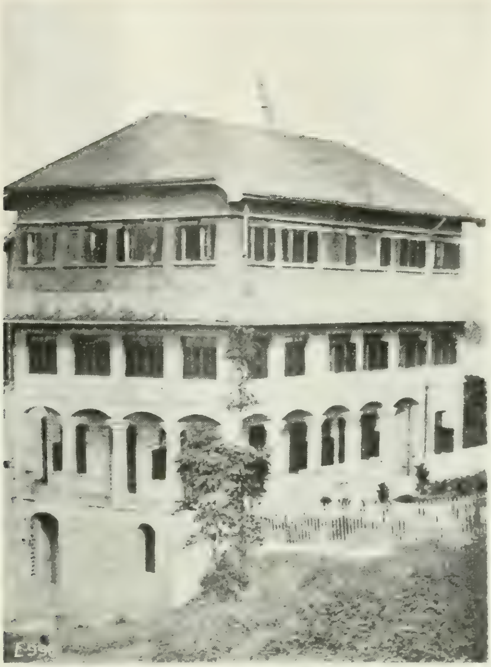


FIG. 3. BANK BUILDING AT MONROVIA, LIBERIA.

difficulties were experienced in connection with the foundation work, owing to the steeply sloping site; the ground floor is approximately 2 ft. above the ground level at the highest point, and about 12 ft. above it at the lowest; as the building is not more than 46 ft. wide on its narrow face, the steepness of the slope will be appreciated.

The walls of the strong room are of reinforced concrete 24 in. thick, and carried down to a foundation on the solid hillside. Electric lighting is about to be installed throughout the building. It will be remembered that Monrovia was recently shelled by a U-boat which attacked the French wireless station.

At *Seccondee*, a large port in the Gold Coast Colony, has recently been erected perhaps the finest building in the whole of West Africa. It is situated at the angle made by High Street and Chapel Street, and the main block presents an unbroken frontage to these two streets of 190 ft., and it is two stories in height, as shown in the *Frontispiece*.

On the ground floor are two wide entrances leading to the porches, flanked by continuous verandahs 6 ft. wide at the narrowest point. The entrances lead to six pairs of folding doors which open on to the public space and main office. The counter is 120 ft. long, and the large office behind is divided up by mahogany screens and grilles, as shown in the photograph of the interior. The two large concrete strong rooms, with heavy strong room doors, are behind the cashier's office, together with specie room, fireproof book-room, stationery room and large document room; manager's and accountant's rooms are on the opposite side of the office.

Staff quarters are provided on the upper floors; a portion of this floor is available by separate staircase for letting off as flats. The building was opened in July 1917 by Lady Clifford, the wife of the Governor of the Gold Coast Colony, and one of the photographs illustrates the building at the opening ceremony. Three interesting views are given of the building in course of construction in *Figs.* 4, 5, and 6; showing the walls, etc., of concrete blocks. In the compound at the rear of the main office building is a large warehouse for merchandise hypothecated to the bank, also native boys' quarters, latrines, etc. The building was originally designed by

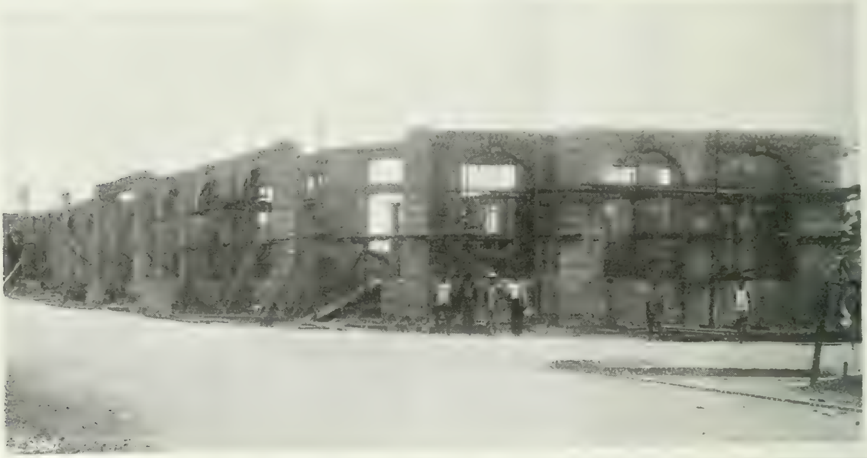


Fig. 4. Premises for Bank of British West Africa, Ltd., at Seccondee, in course of construction

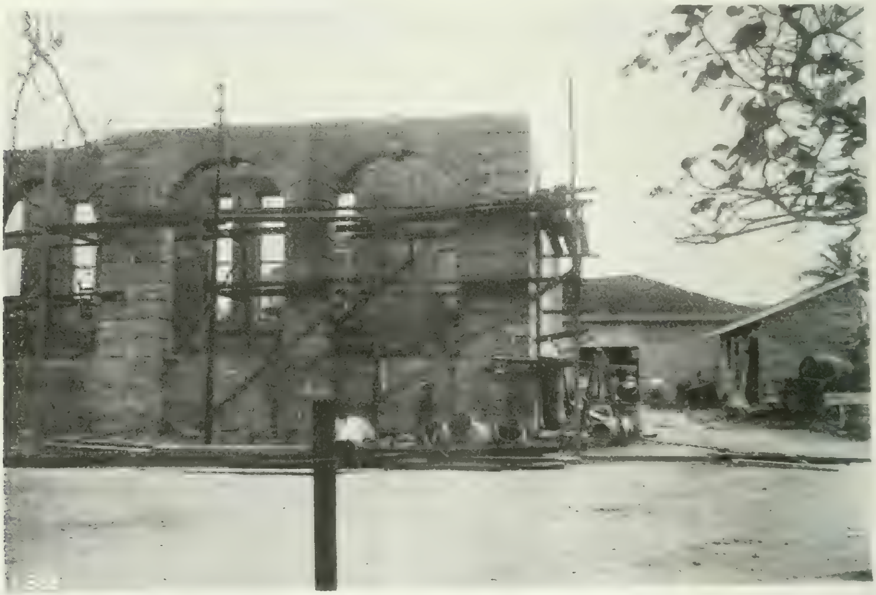


Fig. 5. Seccondee Bank in course of construction.

Mr. C. A. M. Skues, F.S.I., in consultation with Mr. Garner; Mr. Skues joined H.M. Forces, and the architectural work was then carried on by Mr. Stanley Burmester, F.R.I.B.A. Many difficulties, chiefly due to war conditions, were encountered during the progress of the building, and great credit must be given to Mr. Garner for his initiative in solving some of the problems created by shortage of steel. Owing to the necessary Government restrictions on the export of steel, no structural steel was obtainable from this country, although it had been intended to export stancheons and joists for the main structure. Local supplies of steel were used, helped out by mass concrete. A view of the interior in *Fig.* 8 shows the internal columns, in which steel rails embedded in concrete were used, carrying the first floor. Fibrous plaster ceilings, with enriched cornices, made by Messrs. J. Tanner & Son, of Westminster, were exported and fixed in position, but owing to the difficult nature of the landing at Seccondee, some of the ceiling slabs were unfortunately broken.

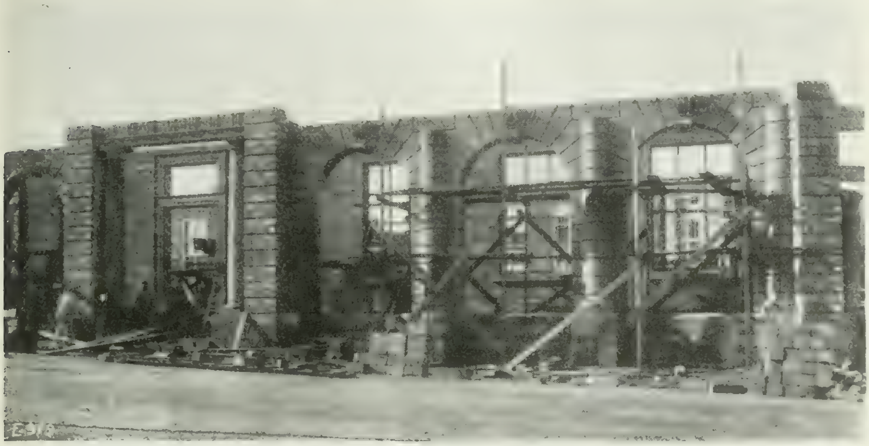


FIG. 6. BANK OF BRITISH WEST AFRICA, LTD., SECCONDEE, SHOWING CONCRETE BLOCK WALLS AND COLUMNS IN COURSE OF ERECTION.

The floor of the public space was carried out in Hopton wood stone, egg-shell polished, with bands of Bleu Tonquin marble forming panels. This floor was supplied by Messrs. J. Stubbs & Son, of Liverpool, and shipped out to Seccondee with fixing diagram to work by. A public clock is to be fixed in the circular panel in the main pediment at the angle of the building. The counter is of African mahogany, stained and French polished, with grilles of similar finish; owing to war conditions it was not possible to provide bronze grilles. These fittings were sent out in sections and fitted together on the job. The general contractors were Messrs. Thompson, Moir, & Galloway, of Accra, Seccondee and Coomassie. At *Accra,* the capital of the Gold Coast, and a prominent port, a new bungalow to provide quarters for the senior members of the staff has been erected by the Bank of British West Africa, Ltd. This is shown in the accompanying photograph (*Fig.* 7), and it will be observed that the roof is covered with concrete tiles, which have successfully withstood a severe rainy season. A motor

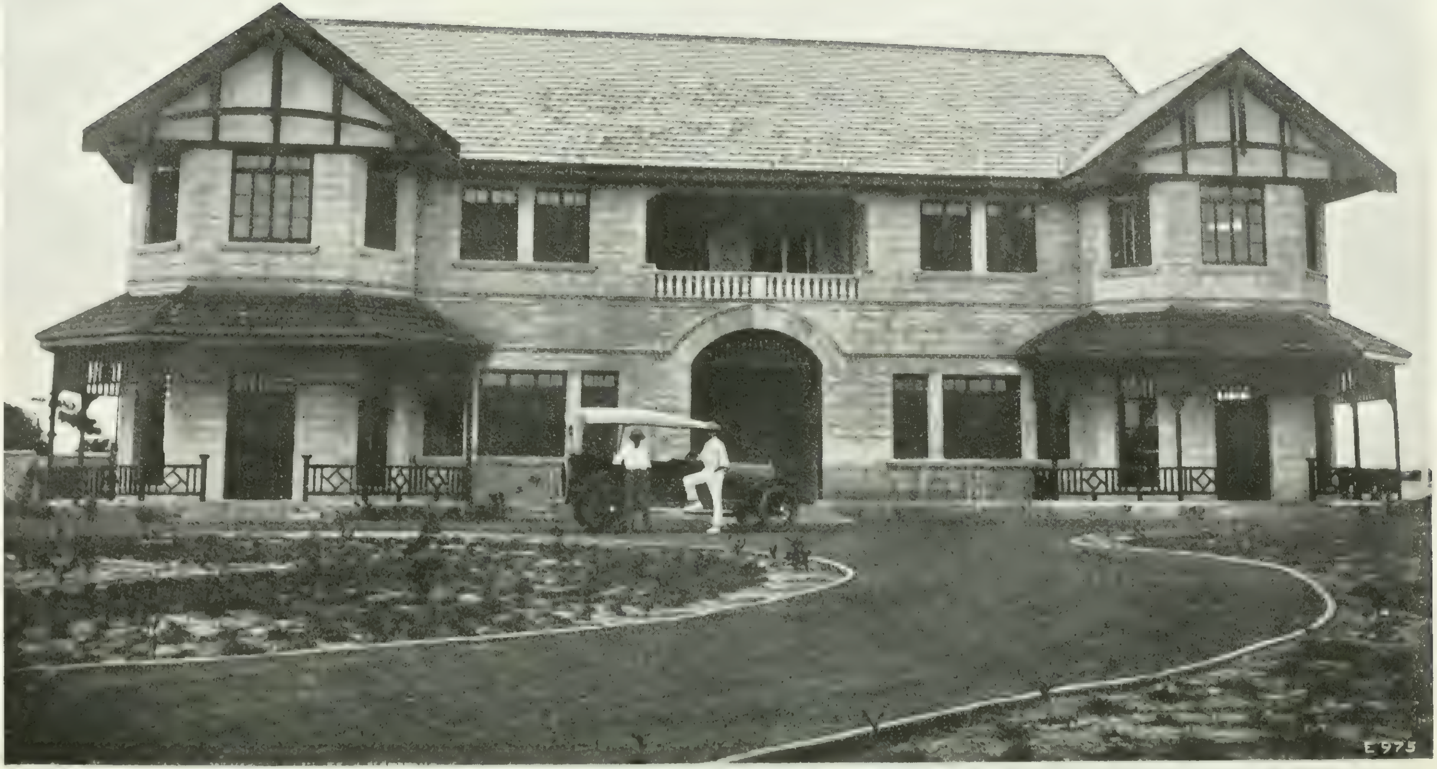


Fig. 7. "Milner House," at Accra, showing cement and sand roofing tiles.

BUNGALOW OF THE DISTRICT MANAGER AND LOCAL MANAGER OF THE BANK OF BRITISH WEST AFRICA, LTD.

garage occupies the centre of the ground floor front, and incidentally it may be remarked that the progress of motor traffic on the West Coast has been remarkable, and, indeed, it is said by authorities that the future of West Africa is very largely linked with road making and motor transport. The building was designed by Mr. J. H. Garner, and carried out under his direction.

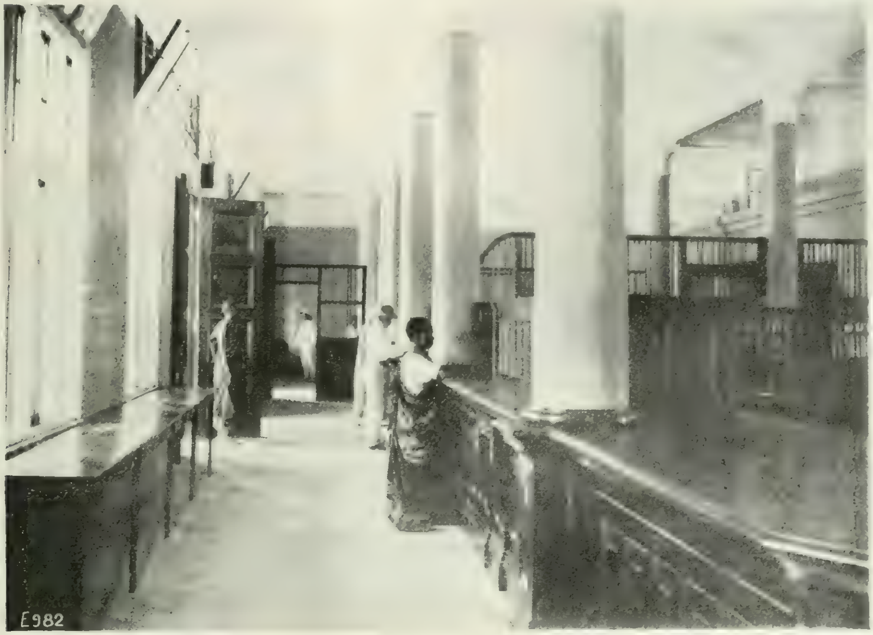
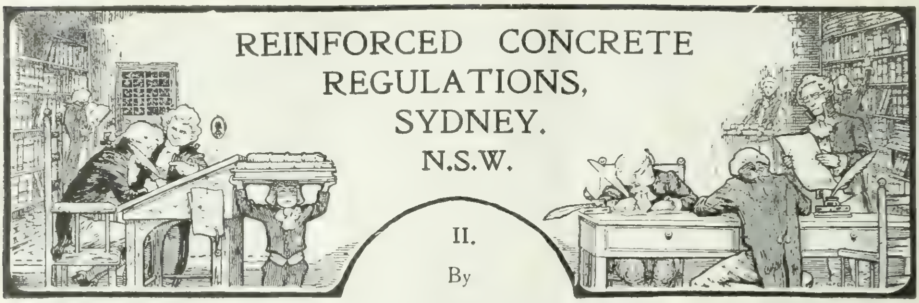


FIG. 8. INTERIOR OF BANK, SECCONDEE

(To be concluded.)



REINFORCED CONCRETE REGULATIONS, SYDNEY. N.S.W.

II.

By

CHARLES F. MARSH, M.Inst.C.E.

(*Continued*)

The first article regarding these Regulations appeared in our May issue on p. 232.—ED.

THE regulations covering bending moments, floor slabs, flat slabs or mushroom floors, columns, working stresses, materials, form work, centering and mixing of concrete, and placing of concrete and steel, follow generally the recommendations of the Special Committee on Concrete and Reinforced Concrete of the American Society of Civil Engineers.

Regulation 36 provides that the exact distribution of loads on beams supporting slabs, reinforced in two directions at right angles to one another, shall be determined in special cases, as they will not be evenly distributed, but ordinarily the variation of the load along the length of a beam shall be considered to be represented by the ordinates of a parabola having its vertex at the middle of the beam. Equations are given for the bending moments and shearing forces on beams under this form of loading for freely supported and absolutely fixed ends.

The height of the central ordinate, according to the regulations, is to be wd, where w is the superimposed load + the dead load, per sq. ft. and d is the distance between the beams in feet.

As printed, this provision would apply to a single slab supported on its four sides by beams.

It is obvious that such a central ordinate would not be correct in this case, although it would be correct for beams supporting slabs on both sides. According to the regulation as it stands, therefore, the central ordinate is double its correct value.

The usual assumption for the loading on beams supporting floor slabs is that the longer beams each support half the load from adjacent slabs, while the shorter beams support the ends of the longer beams with half their weight and loading.

This assumption is obviously incorrect, and it is probable that the parabolic form of loading is more accurate, but neither assumption can be actually true.

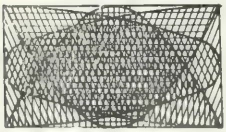


FIG. 1

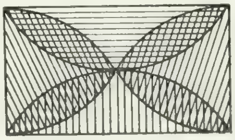


FIG. 2.

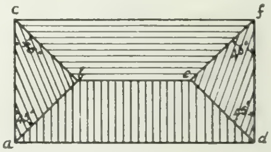


FIG. 3

If parabolas are drawn with a height of vertex wb and wl respectively, as provided in the Sydney regulations, where b and l are the distances between the beams respectively (*Fig.* 1), it will be seen that there are considerable overlapping areas, and this would still be the case if the height of the vertex of the parabolas were $w\frac{b}{2}$ and $w\frac{l}{2}$ respectively (*Fig.* 2), which is the correct loading for a single slab.

It is probable that the actual loading for a single slab approximates that shown in *Fig.* 3, where the loadings given by the areas of the triangles *abc* and *def*, multiplied respectively by w, are taken directly by the shorter beams, while the loadings given by the areas of the figures *cbef* and *abed*, multiplied respectively by w, are taken by the longer beams. When there is a slab on each side of the beam the loading on the beam would, of course, be double the above.

The shorter beams would, in any case, if the junction between the beams was not supported by a column, each have to carry half the weight and loading of the longer beams, as well as the portion of the weight and loading on the slab which is borne directly by them.

The following values are given for the positive and negative bending moments on continuous beams and slabs under uniformly distributed loading, where w=superimposed and dead load per lineal unit, and l=span.

Member and position of moment.	Bending moment.
Floor slabs at centre and supports	$\frac{wl^2}{12}$
Beams at centre and supports, interior spans	$\frac{wl^2}{12}$
Beams at centre, end spans	$\frac{wl^2}{10}$
Beams and slabs continuous for two spans only and with restrained ends at central support and near middle of span	$\frac{wl^2}{10}$
Ends of beams, the negative bending moment will depend on condition of restraint.	
In ordinary cases	$\frac{wl^2}{16}$
In case of small beams running into columns	$\frac{wl^2}{12}$

For beams fixed at the ends, under a uniformly distributed loading, the bending moment at the centre and at the supports is to be $\frac{wl^2}{12}$, and under a concentrated central load $\frac{wl}{8}$.

For uniformly loaded and centrally loaded beams with ends freely supported and for cantilevers under uniformly distributed loading and a concentrated load at the end the bending moments have their usual values.

Regulation 37 provides that for spans of unusual length, or spans of materially unequal length, or for special cases of loading, more exact calculations are to be made.

The first two cases obviously only apply to continuous beams, although this is not stated in the regulations.

Regulation 38 provides that in the case of cantilevers or continuous beams the tensile and compressive reinforcements over the supports shall extend sufficiently beyond the support and the point of contra flexure to develop the required bond strength.

Regulation 39 stipulates that wherever continuous beams are employed, ample foundations must be provided to prevent unequal settlement.

Regulation 40 provides that where beams are framed into a wall girder on one side only, the wall girder shall be designed to resist the torsional moment.

The case of floor slabs supported along four sides is dealt with under Regulations 41 and 42.

Regulation 41 provides that the slabs shall be designed as continuous over the supports, the reinforcement in the bottom between the points of contra flexure being designed for the positive bending moment, while the reinforcement on the top over the supports is to be designed for the negative bending moment.

It further provides that the bars are to be bent up from the bottom to the top at the points of contra flexure, and that if the slab is square, one half of the total bending moment shall be assumed to be carried by the reinforcement in each direction.

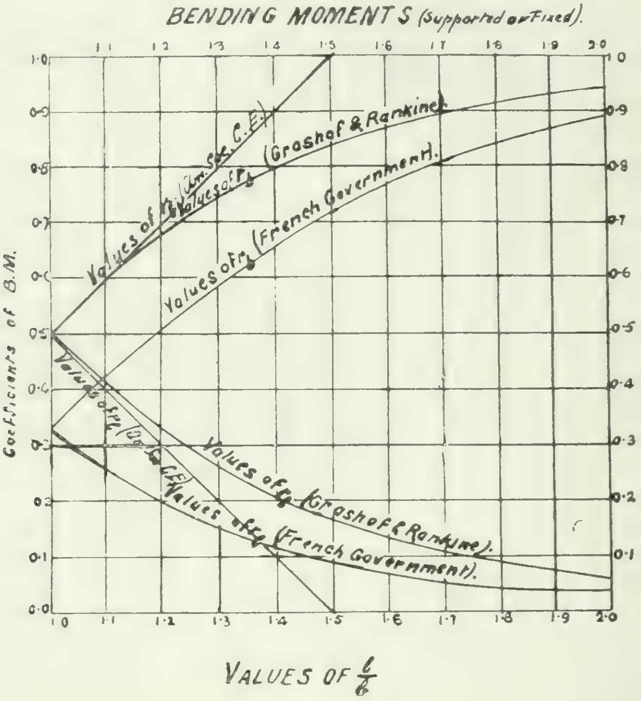


FIG. 4.

Regulation 42 stipulates that if the slab is oblong, and the long side is not less than one and a half times the length of the short side, the total bending moment is to be carried by the transverse reinforcement.

It further provides that if the long side, l, is less than one and a half times the length of the short side, b, the proportion, r, of the total bending moment shall be carried by the transverse reinforcement, while the remainder shall be carried by the longitudinal reinforcement where

$$r = \frac{l}{b} - 0{\cdot}5.$$

Two-thirds of the moments thus calculated are to be assumed to be resisted by the middle half of the slab, and one-third by the outside quarters.

With respect to this regulation the first proviso is more severe than the usual practice of allowing a portion of the bending moment to be resisted by the longitudinal reinforcement until the length of the slab becomes twice its breadth.

With respect to the values for *r*, the above straight-line equation, which is that recommended by the Special Committee of the American Society of Civil Engineers, gives a greater proportion of the bending moment to be resisted in a transverse direction, and a lesser proportion in a longitudinal direction than according to the Grashof and Rankine rule ; except for square slabs.

Fig. 4 shows the comparison of the values of *r* according to Grashof and Rankine, the French Government and the American Society of Civil Engineers, or Sydney regulations.

Regulations 43 to 62 inclusive deal with mushroom floors or flat slabs without beams or girders. These regulations follow the recommendations of the Special Committee of the American Society of Civil Engineers, and it may be presumed that they embody the best practice for such floors, as the membership of this Committee included most of the best-known reinforced concrete experts in the United States.

This form of construction has not, up to the present, been adopted in this country, although it is widely employed in the United States, and with excellent results.

The American Committee state that the treatment recommended by them is necessarily more or less empirical.

Regulation 43 contains a general definition of the flat slab.

Regulation 44 deals with the diameter to be given to the column capitals, stating that the diameter is usually 0·225 of the panel length between centres of adjacent columns.

Regulation 45 provides that the width of a dropped panel, or the thickening of the floor slab sometimes provided throughout an area surrounding the column capital, shall be at least four-tenths of the corresponding side of the panel from centre to centre of columns.

Regulation 43 gives the least thicknesses for the slab, being in inches :

$0{\cdot}024\, l\sqrt{w}+1{\cdot}5$ for a slab without dropped panels ;

$0{\cdot}2\, l\sqrt{w}+1$ for a slab with dropped panels ; or

$0{\cdot}03\, l\sqrt{w}+1{\cdot}5$ for a slab with dropped panels whose width is four-tenths the panel length ;

where l=panel length in feet, and w=the sum of the live and dead loads in lb. per sq. ft.

It further provides that the thickness shall never be less than 6 in., or the thickness of a floor less than one-thirty-second the panel length or a roof slab less than one-fortieth of the panel length.

Regulations 47 to 50 inclusive deal with bending moments and their distribution. They provide that the effective span in a direction normal to the section on which the bending moment acts is the span centre to centre of columns, less two-thirds the diameter of the column capital.

For a square interior panel, where l is the rectangular distance centre to centre of columns, and c the diameter of the column capitals the positive bending moment on the section across the middle of the slab is to be

$$M=\frac{wl}{25}(l-\tfrac{2}{3}c)^2$$

The negative bending moment on a section following the panel edge and column capital is to be

$$M=\frac{wl}{15}(l-\tfrac{2}{3}c)^2$$

If the panel length of an oblong interior panel does not exceed the width by more than 5 per cent. the slab computations may be made on the bases of a square panel with sides equal to the mean of the length and breadth.

Where the length exceeds the breadth by more than one-twentieth and by not more than one-third, the positive bending moments on sections across the middle of the slab parallel respectively to the long and short side must be

$$M_l = \frac{wl}{25}(b - \tfrac{2}{3}c)^2$$

and

$$M_b = \frac{wb}{25}(l - \tfrac{2}{3}c)^2$$

while the negative bending moments on sections following the panel edges and column capitals parallel to the length and breadth of the slab respectively must be

$$M_l = \frac{wl}{15}(b - \tfrac{2}{3}c)^2$$

and

$$M_b = \frac{wb}{15}(l - \tfrac{2}{3}c)^2$$

For the distribution of the bending moments over the lengths of the sections the slab is divided as in *Fig.* 5.

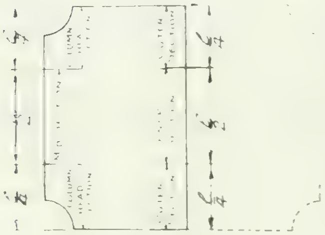


FIG. 5

Of the positive moments, at least 25 per cent. must be provided for in the "inner section" and in the two "outer sections" at least 55 per cent. must be provided for in the case of slabs without dropped panels and 60 per cent. in slabs having dropped panels; except that in calculations to determine the necessary thickness of slab away from the dropped panel, at least 70 per cent. must be considered as acting in the two "outer sections."

Of the negative moments, at least 20 per cent. must be provided for in the "mid section," and at least 65 per cent. in the two "column-head sections"; except that in slabs with dropped panels, at least 80 per cent. must be provided for in the two "column-head sections."

Regulation 51 provides for the moments on wall panels, stating that the coefficient of the negative moment at the first row of columns shall be increased 20 per cent. over that required for interior panels, and that the coefficient of the positive moment at the section half-way to the wall shall also be increased by 20 per cent. It also provides that if beams are not provided along the wall, or the slab does not project as a cantilever beyond the column line, the reinforcement parallel to the length of the wall for the negative moment in the outer portion shall be increased 20 per cent.

Regulation 52 provides that beams must be constructed to carry walls or other concentrated loads which are in excess of the carrying capacity of the slabs, and that beams must also be provided where openings in the floors reduce the strength of the slab below the required carrying capacity.

Regulations 53 to 61 inclusive deal with the slab reinforcement. They provide that the point of contra-flexure on any line parallel to the panel edge shall be taken as one-fifth of the clear distance on that line between the two sections of negative moment at opposite ends of the panel, but that for slabs having dropped panels the coefficient of one-fourth shall be used instead of one-fifth.

That adequate provision must be made to secure the reinforcement in place, and that all bars shall extend on each side of a section of maximum moments to points at least twenty diameters beyond the point of contra-flexure, or be hooked or anchored at the point of contra-flexure.

That for a "column-head section" the bars parallel to the straight portion of the section do not contribute to the negative resisting moment, and that the sectional area of diagonal bars multiplied by the sine of the angle between the diagonal of the panel and the straight portion of the section under consideration, shall be taken as acting as reinforcement in a rectangular direction.

That bars in diagonal bands used as reinforcement for negative moments must extend on each side of a line through the column centre, at right angles to their direction at least a distance of 35 per cent. of the panel length, and diagonal bars used as reinforcement for positive moments must extend on each side of a diagonal through the centre of the panel at least a distance of 35 per cent. of the panel length.

That not more than one-third of the bars in any direction must be made of a length less than that between the centres of columns in that direction.

That continuous bars must not be bent up at the same point of their lengths, but the zone in which the bending occurs must extend on each side of the point of contra-flexure, and must cover a width of at least one-fifteenth of the panel length and that in a four-way reinforcement the position of the bars in both diagonal and rectangular directions must be considered in determining whether the width of zone of bending up is sufficient.

That at constructional joints extra reinforcing bars must be provided sufficient to increase the area of the bars by 20 per cent., and they must extend not less than fifty diameters beyond the joint on each side.

Regulation 62 provides that in calculations for diagonal tension or shearing stress, the total shearing stress on two " column-head sections " shall be considered to be one-fourth of the total load on the panel for a slab of uniform thickness and three-tenths of the total load on the panel for a slab with dropped panels.

(To be continued.)

MEMORANDUM.

A Tasmanian Reinforced Concrete Bridge.—In a recent issue of *The Commonwealth Engineer* Mr. W. Nimmo, Engineer, Public Works Department, Hobart, gives the following short particulars of the first reinforced concrete bridge erected in Tasmania The bridge, which is situated at Dilston, carries the main road from Launceston to Georgetown over Nelson's creek. The bridge consists of three spans (not continuous) of 38 ft. each, and supported on two abutments and two piers, the deck being 30 ft. above the creek bed. The roadway, which is laid with tarred metal, is 16 ft. wide, the width of the bridge over all being 18 ft. There are four T beams, 15 in. wide and 35 in. in depth, including the deck slab, which is 6 in. thick. Each beam is designed for a maximum moment of 3¾ million inch pounds, and the reinforcement consists of 1⅛ in. round bars, eight at the bottom and three at the top. The piers are unbraced frames, consisting of three legs 18 in. square, joined by horizontal struts, all members being reinforced to resist bending moments.

The whole of the reinforcement consists of plain round bars, most of which the department had available on other works. The use of this material necessitated minor alterations in the original design, and the cutting and welding of some of the main bars, such welding, however, was restricted to the extreme ends of bars that are hooked.

The rails consist of old boring pipes with internal joints. These pipes are about 3½ in. external diameter, and give a better appearance than ordinary 2 in. water pipe, the present cost of which is very high.

The bridge contains 120 cu. yds. of concrete and 12½ tons of steel. A small training wall of concrete has also been built on each side of the creek. The cost of the bridge, including training walls and road approaches, was about £1,150. The bridge was designed by Mr. Nimmo.

A Reinforced Concrete Road in U.S.A.

CONCRETE ROADS.

Some Interesting Highway Tests and the Application of the Method on Industrial Works.

A set of tests, at once interesting and instructive, has recently been carried out in California with a view to ascertaining the amount of pull necessary to keep a trailing load in motion after it had been started on different types of roadway. The load of 3 tons gross consisted of a farm wagon loaded with sacks of rice, and the motive power was supplied in the horse-drawn tests by a team of draught horses, and in the motor tests by a two-ton truck.

Great care was taken that the conditions should be kept uniform throughout the tests, and to this end, the same wagon, the same load, the same horses or truck, the same driver, the same speed, and the same weather conditions were selected. The results obtained were as follows :—

Character of Road.	Pull in lbs. per ton.
Loose gravel, not packed down, new road	263
Earth road, stiff mud on top, firm beneath	218
Earth road, fine dust	92
Gravel road in good normal condition	78
Water-bound macadam, good condition	64
Concrete base, $\frac{3}{8}$-in. skin top of asphaltic oil and screenings	49
Unsurfaced concrete	28

In other words, a load that just measured up to the capacity of four horses on an unsurfaced concrete road, will require nine horses on a waterbound macadam road, thirteen on a dry earth road and thirty-one on an earth road with stiff but shallow mud ; or to put it in a different way comparing other types of road with the unsurfaced concrete, there is a waste of 128 per cent. of power in the case of waterbound macadam, 228 per cent. on the dry earth road, and 678 per cent. on the earth road with stiff shallow mud.

The above tests were made in dry, warm weather, in order to eliminate the complication of a wet, muddy surface. Had they been made under the latter conditions the percentages would undoubtedly have been very much higher.

To both the farmer, who does his work mostly with horses, and the motor owner whose power is supplied by petrol, this is a matter of grave concern, since in each case waste of power means inefficiency, and therefore loss.

Another series of tests, we learn from the *Railway Age*, was carried out some time ago in the shopyards of the Atchison, Topeka and Santa Fé Company at Topeka. Here the haulage of material was done by horse and cart and by electric trucks over earth and cinder pathways. This, however, was found to be costly. An exhaustive study of hauling and trucking conditions was therefore made, including a series of tests with an electric truck, the object being to determine the difference in power necessary to start and pull a loaded truck with and without trailers over earth, oiled cinders, wood, metal, and concrete roadways.

The final result of these tests showed that an electric truck could handle only a small percentage of its full tonnage when used on earth or cinder roads, even when these roads were in good condition, and clearly indicated the great advantage of concrete roads over wood, metal, and especially oiled cinders, the truck handling four to five times as large a load at a smaller power output on the concrete roads than on the last-named of the others. In view of these conclusions the Company has laid down about 2½ miles of concrete roadways a description of which appeared in the May issue of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

Apropos of the above, a concrete road has recently been laid down at the works of Messrs. Jos. Baker & Sons, engineers, Willesden Junction, under the superintendence of Mr. S. W. Moscrip, the engineer.

Having studied the concrete roads of America and of this country, and examined the question in all its bearings, Mr. Moscrip was satisfied that a concrete road was calculated to meet, more satisfactorily than any other, the demands made upon it by the heavy traffic which a road of this description has to carry ; the Company therefore decided to give this method of construction a trial.

The foundation, with which great care was taken since this is an important factor of success in concrete road-making, consisted of a mixture of clinker and ballast well rolled and consolidated. The kerbing which was laid first is 1 ft. in depth, and is battered on both sides, being 6 in. wide at the top and 9 in. at the bottom. The concrete for the road itself is 6 in. in thickness, and was laid in two courses, a lower course of 4 in., consisting of a mixture of 1 part Portland cement and 5 parts coarse material, and an upper layer of 2 in., consisting of 1 part Portland cement, 1 part sand, and 2 parts pea shingle, graded up to ¾-in. diameter. The reinforcement consists of steel mesh. Adopting the principle, to which, where reinforcement is used, recent experiments seem to point as being sound, no expansion joints were provided. The concrete was laid in alternate bays, and the material in the intervening spaces was laid close up to the concrete already in position. The surface was worked over by a trammel, shaped to the camber of the road, and was afterwards finished with a wooden float. When the concrete was sufficiently hard, the road was covered to a depth of about 2 in. with ashes, which were kept constantly moist, and allowed to remain for three or four weeks.

The road, so far constructed, is about 200 yds. in length and 24 ft. wide, and the result is satisfactory in every way. The surface is even but not smooth, and presents a " dead " face which affords an excellent grip for horses and motor vehicles, and enables each to work up to its maximum power ; and although some two or three hundred tons of traffic pass over the road daily, there is in it neither crack nor flaw. Indeed, so satisfied is the engineer with the result of this experiment, that the Company has in contemplation the construction of concrete roadways throughout the whole of its yards.

Another example of the concrete road in connection with industrial works is that which forms the approach to the Ingress Abbey Mills of the Wall Paper Manufacturers, Ltd., at Greenhithe. The length which has been concreted is about 800 ft., and the width of the road is 18 ft. between the kerbs. Concrete kerbing, 6 in. thick, was first moulded *in situ*, the mixture used being 3 of sand to 1 of cement. No reinforcement was used for this kerbing, but to allow for contraction, joints were formed with deal strips ¼ in. thick, spaced every 12 ft. The concrete of the road was 6 in. in thickness, and consisted of a bottom 4 in. of 6 : 1 mixture, and a finishing surface 2 in. thick of 3 : 1. It was reinforced throughout with B.R.C. fabric No. 9, placed as nearly as possible 3 in. above the bottom—*i.e.*, in the centre of the concrete. In order to reduce the number of joints (which are a source of weakness in concrete roads), each day's work was done continuously in one bay, and sufficient space was left between one day's work and the next to allow of the intervening bay being put in afterwards when those on each side were set. One thickness of tarred paper was placed against the ends of the completed bays before the intervening bay was filled in. The reinforcement was placed so that it stopped 2 in. from the end of each bay, and also 2 in. from the kerbing on each side in order to ensure that it was protected by concrete from any risk of corrosion.

The whole road is on a gradient from one end to the other, but the gradient varies throughout its length. A cross fall to both kerbs of 1 in 50 was provided. The contractors were Messrs. Wm. Griffiths & Co., Ltd., Hamilton House, Bishopsgate, E.C.

The last of the photographs illustrating these notes shows a concrete road recently laid down at an important factory in the South of England. The road runs the whole length of the main buildings, some 2,500 ft. in all.

During the construction of the factory a hard core roadway had been formed approximately on the same lines as the new concrete road, for which a good foundation had thus been prepared. Preparatory to starting work on the concrete road the top of the hard core was picked over, screened, levelled and rolled. Concrete kerbs which had previously been cast in moulds were then laid on a concrete bed on either side of the new road, and served as forms for the concrete which was laid *in situ*.

The roadway itself is 10 ft. wide between the kerbs, with double width passing-place, and consists of 6 : 1 cement concrete 6 in. thick, laid direct on the hard core referred to. No reinforcement of any kind was used, but the concrete was deposited in alternate sections 10 ft. 8 in. in length and the full width of the road. Upon this was laid a surface coat, 1½ in. in thickness, consisting of granolithic paving. When these sections had set, the intervening portions were laid in a similar manner.

The road is used chiefly by rubber-tyred three-ton petrol lorries delivering goods to and from the various parts of the factory.

The concrete work was carried out by Messrs. Stuart's Granolithic Company.

The above are examples of what may be successfully accomplished by enterprising private firms, but there is the larger question of our public roads, and, as Mr. F. A. A. Talbot, writing in *World's Work*, says, it is a moot point whether there is any issue of such pronounced significance to the community at large at this moment as the condition of our highways. They have been subjected to extraordinary traffic, and even what may be described as legitimate traffic, with its coincident wear and tear, has attained a volume which has eclipsed the most liberal anticipations. Every effort has been, and still is being made to keep the arteries of traffic in a fairly passable condition. But the responsible authorities are faced with prodigious difficulty. They can do little but carry out hurried patchwork operations here and there on the principle that a stitch in time saves nine, but that is all.

Reinforced Concrete Road at the Works of Messrs. Jos. Baker & Sons.

Reinforced Concrete Road at the Works of Messrs. Jos. Baker & Sons, showing the Truck Lines.

Reconstruction, continues this writer, is strongly advocated in preference to renovation, owing to the experience acquired by road-building engineers in the past. This has demonstrated repeatedly and conclusively that it is far cheaper to commence *de novo*, and to build for the traffic which has to be met, than to adapt that existing to satisfy the conditions imposed. The resolve to build the roads to accommodate the heavy motor traffic raises the question as to whether the time has not arrived for us to revise the whole of our ideas concerning road engineering.

Fortunately the problem of road construction in such a manner as to stand up against the heaviest and swiftest traffic is not insuperable. During the past few years the reinforced concrete method has gained increasing vogue, and has achieved widespread application in the laying out of new roads, more particularly in such countries as the United States, where the necessity for improved rural communications has become emphasised ; and, certainly, the results so far achieved point conclusively to the durability, strength, and traffic-resistance qualities of this form of construction. One great advantage of the system is that a monolithic road is secured, which does not develop pot-holes, which can be cheaply and easily cleaned, which is dustless, and which, when properly built, is capable of bearing the heaviest class of traffic.

A Concrete Road at a Factory in the South of England.

It has been objected that access to gas, water, and other mains as well as underground cables would be rendered more difficult and expensive, and that in breaking the surface to reach these underground services widespread destruction to the road would be necessary, even if the actual metal skeleton were not somewhat weakened. But experience has disproved these contentions.

Several more or less experimental stretches of public road in this country have been laid in concrete. In one instance the road is subject to the strains and stresses set up by the vehicles emerging from two well-known heavy lorry factories.

The stretch was built before the war, and was designed to meet the standard lorry traffic of the day. During the past three and a half years it has been submitted to the constant strain of specially built military vehicles, and even this strenuous unusual traffic has failed to precipitate the slightest sign of weakness. So satisfied is the engineer with the result that he has expressed his intention of putting down similar roads in future, and from the experience gained in other experimental stretches of roadway many of our foremost road designers and builders have come to the conclusion that the reinforced concrete highway will become the road of the future

Concrete Roads in Auckland, N.Z.—Some time ago* we were able to publish some short particulars regarding the reinforced concrete road constructed at Auckland, N.Z., namely, Little Queen Street, one of the important thoroughfares of that city. The following is a paragraph which has appeared in a recent issue of *The Commonwealth Engineer* regarding this street, which has been laid for two years, and the views expressed as regards concrete roads generally will no doubt interest our readers :

" The works committee of the Auckland, N.Z., city council, having discussed the question of permanent paving of streets and roads, the mayor, Mr. J. H. Gunson, states that the ratepayers can now take it as definitely settled that the material to be utilised in future for this work would be concrete. The council was satisfied that the cost of asphalte and wood blocks was 100 per cent. more than that of concrete. The two former were, therefore, things of the past as far as Auckland was concerned. Concrete paving would be used wherever it was practicable. This material was giving splendid results, particularly when coated with a special preparation, as in the case of Little Queen Street, where the paving had been laid for two years and proved effectual, in spite of very heavy traffic. A vigorous concrete roading policy would be instituted by the council immediately after the war, when it was hoped that Ponsonby Road and other main roads would receive attention. The only remaining large concrete paving proposition was that of Beach Road.

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* December 1916, page 668

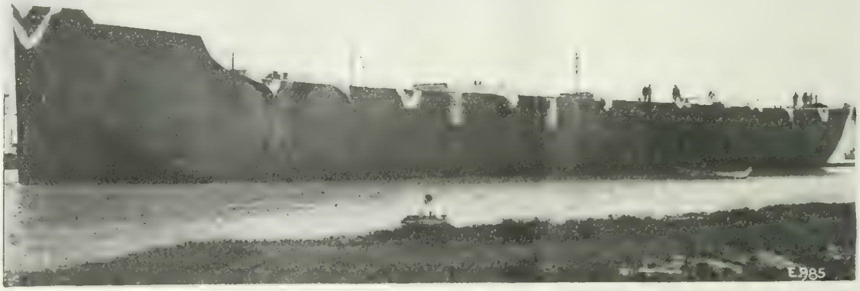

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FIG. 1. THE REINFORCED CONCRETE SHIP "FAITH" AFTER LAUNCHING.

SOME NOTES ON CONCRETE SHIPBUILDING.

GREAT BRITAIN.

IN our last issue we briefly referred to the first large sea-going concrete vessel built in the United Kingdom, and which is to be taken over for and used by the Government.

The accompanying illustrations (*Figs.* 2 to 4) show this vessel completed, and for the convenience of our readers we would briefly repeat that the dimensions of the vessel are :—Length, 150 ft. ; breadth, 24 ft. 6 in. ; depth, 13 ft. 6 in. ; draft, 10 ft. 11½ in. The barge has a displacement of about 900 tons and a dead-weight carrying capacity of 400 tons on 11 ft. draft.

It is divided by four watertight bulkheads in five compartments.

The forward compartment is used for stores, holds, and chain lockers, and the aft compartment for crew's quarters.

The barge is a towing barge for sea-going traffic and is fitted with the necessary towing appliances.

Being the first large concrete vessel built in this country, it was thought advisable to make it of considerable strength, and both in designing the vessel and also in carrying out the work strength rather than lightness or economy has been the main consideration.

To be able to make close comparisons between this vessel and steel vessels, it has been constructed according to the ordinary ship lines, which, of course, has added greatly to the labour and cost of constructing the wooden casing for the concrete, in order to get the correct curves both longitudinally and transversely, but the result has been a vessel of pleasing appearance, and, as far as can be estimated, also of superior strength.

The vessel has been built according to Lloyd's regulations and under their inspection, and it has been classified "A1" by that Society.

About 260 cube yards of concrete and 65 tons of steel bars were used in the construction of the vessel.

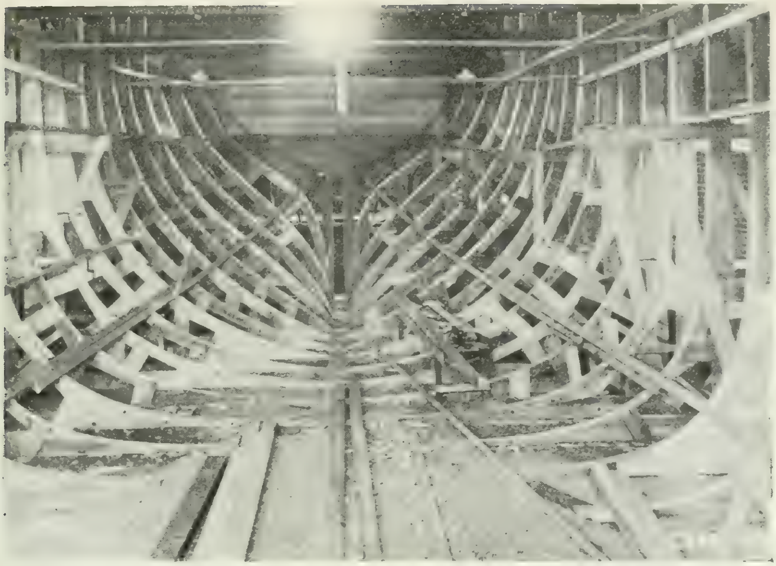

Fig. 2. View of Wooden Ribs, showing the shape of the boat stern. Close boarding is nailed to the ribs to form a mould for the concrete. An outer and inner mould are constructed between which the concrete is cast.

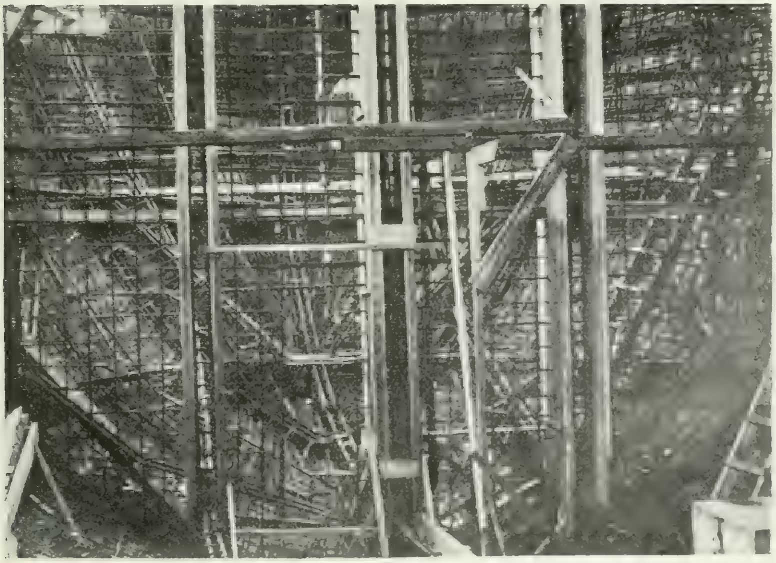

Fig. 3. Showing the completed steel reinforcement near the bows.

The First Reinforced Concrete Seagoing Vessel built in Great Britain.

From notices which have appeared from time to time in our daily press we gather that there is a great activity at the present moment in the direction of concrete shipbuilding in our various national shipyards, and our attention has been drawn to the work that is being done at the Wye shipyards, where concrete is being extensively used for the building of vessels.

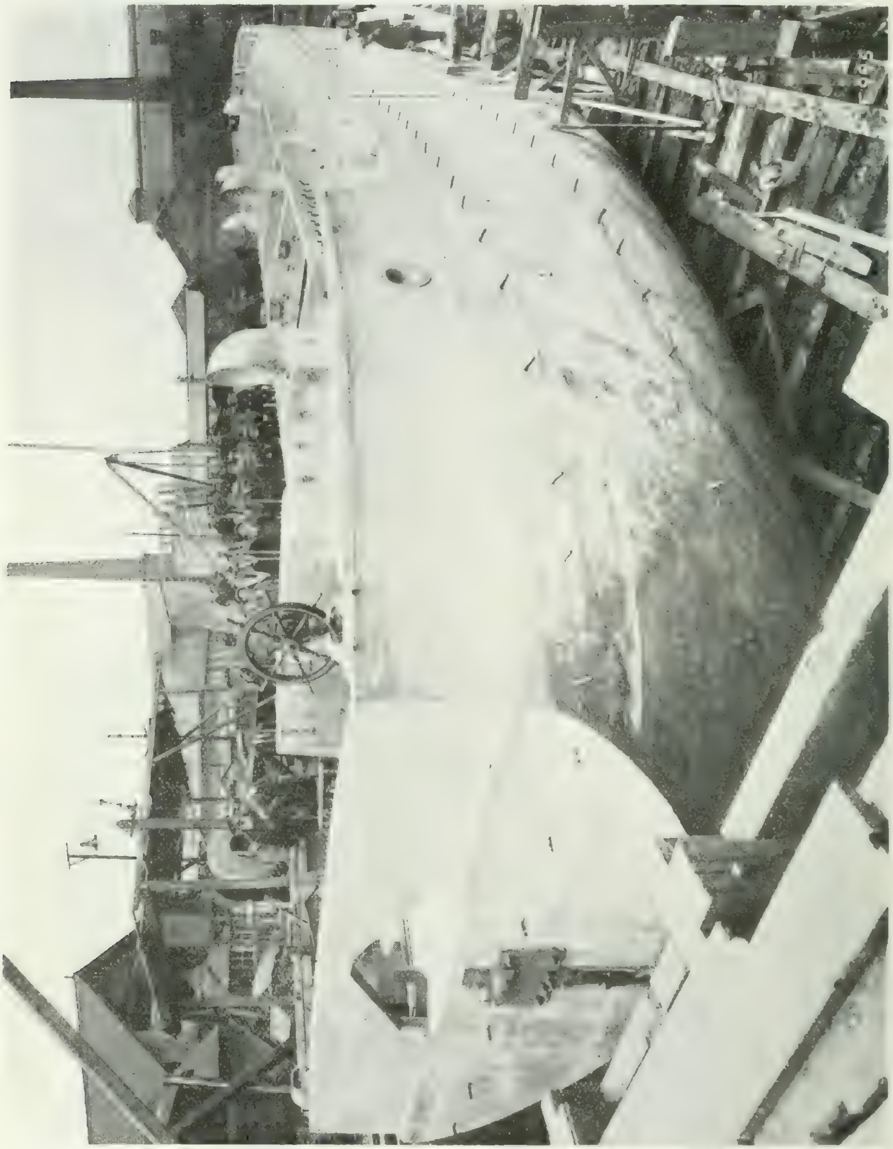

Fig. 4. View of Stern and Starboard Side.

The two rows of bolts projecting from the concrete are for attaching the wooden fenders which protect the concrete.

THE FIRST REINFORCED CONCRETE SEA-GOING VESSEL BUILT IN GREAT BRITAIN.

UNITED STATES.

In our last issue we were able to give particulars of the *Faith,* a 5,000-ton vessel erected in the United States. We showed the vessel in course of construc-

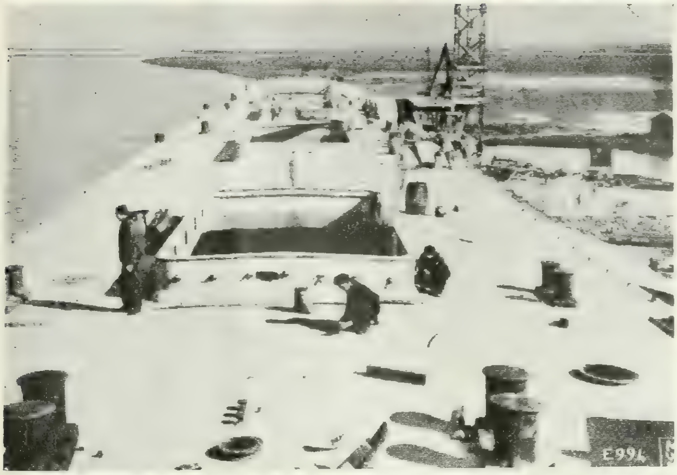

Fig. 5. Deck View of the Reinforced Concrete Steamship "Faith," built in U.S.A.

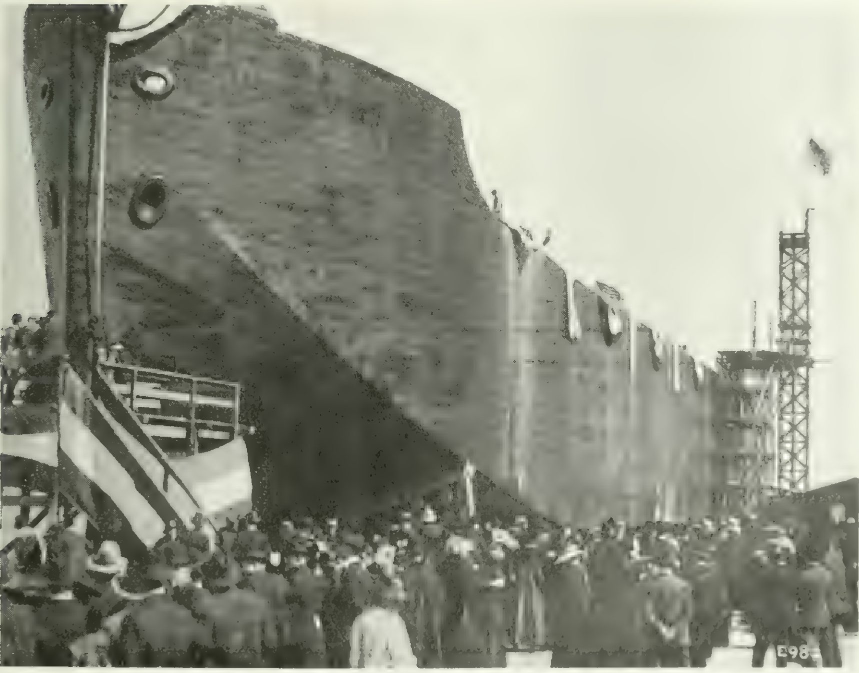

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Fig. 6. View of the "Faith" prior to launching.

tion, and are pleased to be able to present in *Figs.* 1, 5 and 6 views of the completed ship. We learn that she recently ran a satisfactory trial trip.

The following is a cablegram received from Chicago just prior to going to press:—

> "Concrete steamer Faith San Francisco to Vancouver arrived Seattle rough voyage eighty mile gale vessel absolutely seaworthy."

MEMORANDUM
ON CONCRETE SHIPS.

THE following are some questions put and answers given in the House of Commons on May 8th regarding concrete ships :—

Mr. P. A. HARRIS asked the First Lord of the Admiralty whether Italian concrete ships have been built and have been in regular service in the Mediterranean and in the Adriatic some ten years ; and whether he will state the tonnage of the largest British-built concrete sea-going vessel afloat, and how many British-built concrete sea-going vessels of over 400 tons gross register are afloat ?

Mr. PRETYMAN : It is, so I am informed, the fact that the first concrete vessels were built in Italy, but they were of very small dimensions and of no commercial value. In fact, some of them were small rowing boats. The largest concrete vessel actually afloat in English waters is a barge of a little under 400 tons, and this is the only one which has so far been launched.

Mr. HARRIS asked the First Lord of the Admiralty how many reinforced concrete ships have been constructed in the United States ; if any have reached this country to serve as a model for shipbuilders in the United Kingdom ; and, if not, whether arrangements can be made for one of these vessels to visit England ?

Mr. PRETYMAN : As far as I am aware, the first reinforced concrete ship constructed in the United States was launched at San Francisco some six weeks ago. This vessel has a dead-weight carrying capacity of 5,000 tons, but beyond this vessel no other of the same material has been launched. No vessel built of reinforced concrete has so far reached this country from the United States, and it is unlikely that the vessel which I have already referred to will be sent to the United Kingdom. Should it be found possible to send such a vessel across the Atlantic, my hon. friend may rest assured that every advantage will be taken of such a voyage in order to submit the vessel to a practical test and to obtain such information as will enable construction of vessels of similar types to proceed as rapidly as possible.

Mr. HARRIS : Have returns been obtained from America as to the success or otherwise of these particular ships of 5,000 tons ?

Mr. PRETYMAN : We have had no experience. It was only six weeks ago that the ship was launched.

Mr. WILES asked the First Lord of the Admiralty whether he has received detailed technical information as to the sea-going vessel of 5,000 tons that has been launched in the United States, and of which a number of duplicates are being laid down ; whether he will state if any encouragement is being given in this country, either to existing shipbuilders or newly-formed enterprises, to construct similar concrete ships of large tonnage; and why, having regard to the necessity of economising steel, the endeavours of his Department appear limited to the construction of vessels and barges of only 1,000 tons and under?

Mr. PRETYMAN: Yes, sir; full particulars of the vessel to which my hon. friend refers have been received in this country, and full advantage is being taken of this information. Every encouragement is being given by the Admiralty to this new industry, several newly-formed yards having been laid down specially for constructing concrete craft, while existing shipyards have been encouraged to form branch establishments for the same purpose without interference with the building of steel vessels. Whilst it is true that at present no vessels of more than 1,000 tons are being constructed to the order of the Admiralty, it should not be forgotten that there was a very urgent demand for vessels of small tonnage which could be rapidly constructed. In view of this it was decided to concentrate on the smaller craft until more experience had been obtained as to the construction of such craft, and, what is of much more importance, their behaviour when at sea.

My hon. friend will realise that in a new method of construction such as this there are very many details of which full knowledge can only be acquired by experience. He may rest assured, however, that the building of vessels of reinforced concrete is receiving the closest attention, and that every advantage will be taken of the knowledge that is being obtained.

MEMORANDA.

An Improved Method of Placing Conduit in Concrete Forms.—In a recent issue of *Electricity* Mr. W. O. Myers gives the following description for an improved method of placing conduit in concrete forms:—

"The method adopted is that of placing steel conduit in the forms used for concrete foundations, walls, etc., so that it can be bent slightly after the forms are removed to correct errors of alignment. I used this scheme in placing conduit in the foundation for a steam turbine, where the starters for motor-driven auxiliaries were mounted in the foundation piers. By having the conduit free from the concrete for a distance of 4 or 5 in. back from the face of the wall, I was enabled to bend the conduit end sufficiently to make the conduit fittings true with the face of the wall.

"The scheme consists in simply wrapping rope or staging around the conduit to be imbedded in concrete. The rope can be pulled out after the forms are removed, leaving the conduit free from the concrete for a few inches back from the face of the wall so that it may be bent slightly to correct any of the usual errors of alignment. If large rope is used, it should be plastered over with clay and wrapped with paper before the concrete is poured, and if heavy staging is used it is better to use more than one layer."

Reinforced Concrete Poles.—Reinforced concrete poles are used for a 22,000-volt power line six miles long, at Brentwood, California, supplying a load of about 2,800 horse-power. The poles are tapered beams, reinforced symmetrically on two sides, and are 41 ft. long, 17 in. square at the base, and 8 in. square at the top. The spans vary from 250 ft. to 390 ft. For economy of material, two sizes were designed; the heavier ones are used at each sub-station and for every fifth pole on the line, as well as at crossings. The lighter poles serve for intermediates. The cross-arms were moulded with the poles, and the whole work of moulding was done on the ground on account of the great weight of the finished pole—averaging about four tons. In the cross-arms the reinforcing is of steel angles, which carry the insulator pins directly, so that even were the concrete to be broken from the arms, the stability of the conducting system would not be impaired. The average cost per pole erected was a little less than £14.—*Engineer.*

CONCRETE UTILITIES.

A STUDY OF "THE STONE AGE" IN LONDON.

ATTENTION has been called from time to time in the pages of this journal to the many and varied uses of concrete for the making of small products, quite apart from its advantages and its utility for large structures and buildings generally. The difficulty of obtaining timber and its ever increasing price, as the war progresses, have been important factors in necessitating the finding of substitutes, and to a very large extent concrete has met this difficulty. Our readers will recall not only the references we have made from time to time to the small concrete productions but the numerous illustrations that we have been able to present of work actually carried out in this direction. But, undoubtedly, better than the written word or illustration is the visible demonstration of the actual object. The Concrete Utilities Bureau may therefore be congratulated on the excellent collection it has on view at 143, Grosvenor Road, London, S.W. These examples are at once interesting and instructive and afford convincing testimony of what can be done with concrete. Space does not permit of our dealing at length with the many articles which are to be seen, therefore we here briefly classify them.

BUILDINGS.

In referring to work under this heading, we confine ourselves to what may be termed the minor accessories, and not to structural work itself. The builder who can spare time to make an inspection will see architraves, carved and moulded panels, cast letters for fascia, roofing tiles, hollow blocks, window heads and cills, partition slabs, steps, surfaces of various colours and textures. The last-named item is of importance to the user of concrete, for what some deem its unattractive surface is one of the most frequent arguments brought against it when discussing its applicability for houses, cottages, and the like. The variety and artistic colouring of the decorative panels shown give ample evidence of what can be done to overcome this objection.

PUBLIC AUTHORITIES.

The municipal engineer will find himself well repaid by a visit to Grosvenor Road. There are many things of special interest to those who have control over municipal and rural services. We mention especially such articles as for example, culvert blocks, direction posts, paving stones, septic tanks, sewer pipes, inspection chambers, kerbing and channelling, lamp-posts, piles, manholes, headstones for graves, tree guards.

With regard to the last named, we would mention that these are used as guards to protect tree roots in footpaths.

RAILWAYS.

The intense interest shown by many of our most important railway companies in the use of concrete for small products must be evident to anyone who pays a visit to the above address, and also to those of our readers who are cognisant of the articles we have published dealing with this subject. The Great Western, London and South Western, North Eastern, and Great Northern Railways have special depots for the making of concrete necessities for their stations and general requirements of the line. The work done in this way is extensive and excellent. The three Companies first named have contributed some splendid examples, and these form a valuable and attractive addition to the collection. They include culvert blocks, platform coping and slabs, platform walls, signal posts, fencing posts of every description, gate posts, tanks and troughs, etc.

Railway Sleepers.—The interesting and far-reaching experiments made under this heading will be fresh in the minds of our readers, as we recently presented a detailed review of the work that has been carried out and is in progress not only here, but also in America, India and the Colonies. It may be safely stated that concrete sleepers are finding considerable favour for light railways, sidings and shunting tracks and such developments have been made that their adoption on the main line is regarded by some authorities as a certainty in the future and their success on some Indian railways justifies this opinion.

There are several kinds of block sleepers exhibited, and we understand that some of these have come through very satisfactory trials. One in particular, sent by the N.E.R., which has just been removed from the main line at York, where it has been in constant service over four years. Whilst on this subject we may add that the concrete railway sleeper should find a greater use in industrial works, collieries, dockyards, etc., where there are innumerable tracks of more or less light wagon lines.

THE ESTATE AND FARM.

The uses to which concrete can be put on the estate and farm include the following :—Mangers, troughs and tanks, stable paving, garden frames, steps, fencing posts, gate posts, pergolas, ornamental products, such as balustrades, vases and pedestals.

Examples of all these may be seen, and undoubtedly they claim special attention in view of the great developments that may be expected to take place after the war in connection with our agricultural and rural districts.

To these, we are informed, will in time be added models of cow stalls, piggeries and a silo.

MINES.

The substitution of concrete for timber in mine work is a point which calls for very great consideration among our colliery owners and mining engineers. In our last issue we printed a very instructive Memorandum drawn up by Mr. Geo. Knox, of the South Wales School of Mines, dealing with concrete mine supports. In former issues we have referred to the many uses for which concrete is suitable in connection with mining engineering, particularly the concrete pit prop, which could so well and advantageously take the place of the timber one.* Two concrete pit props are included in this collection.

The firms and others, apart from the Railway Companies above referred to, who have sent specimens of their concrete specialities many of which we have reviewed, are as follows :—Messrs. Sharp, Jones & Co., Parkstone, Dorset; Stuarts Granolithic Co., Ltd., 45, Bedford Row, W.C.; Patent Victoria Stone Co., 155, Bishopsgate, E.C.2; Patent Impervious Stone Co., Rutland Wharf, Hammersmith, W.; Old Radnor Trading Co., Kington, Herefordshire; Tidnams, Ltd., Wisbech; Winget, Ltd., 25, Victoria Street, Westminster, S.W.; The Atlas Stone Co., Coldhams Lane, Cambridge; County Borough of Croydon; Borough Engineer of Aylesbury; The Permanent Way Improvements Co., Ltd., 95, Colmore Row, Birmingham; The Gas Light and Coke Co., Beckton Works.

In conclusion we may state that those who avail themselves of the general invitation to inspect the Show Room of the Concrete Utilities Bureau will be well rewarded.

The chief office of the Bureau, of which Mr. T. J. Clark is the manager, is at 6 Lloyds Avenue, London, E.C.3.

MEMORANDA.

Defence of the Realm Regulations (Regulation 30a). Power Driven Machine Tools or Woodworking Machines and Treadle Lathes for woodworking or metal (3 in. centres and over) come under the above regulation.

Intending purchasers must make application for permission to purchase the machines they require to the Executive Officer of the Area Clearing House Board in their district.

Firms (including Auctioneers) must obtain permission to sell machines from the Controller of Machine Tools, Charing Cross Buildings, Embankment, W.C.2.

The New Royal Exchange Building, Calcutta.—From an interesting publication sent us by Mr. I. C. Banerjee, engineer, builder and contractor, Calcutta, we learn that one of the most interesting features of the New Royal Exchange at Calcutta, from a constructional point of view, are the large Loggia columns of the main order, erected in reinforced concrete. These columns have a clear height of 41 ft. 2 in. and are battered from 3 ft. 4 in. at the base to 3 ft. at the top. The reinforcement consists of eight 1 in. steel bars supported at 12-in. intervals by $\frac{3}{8}$ in. round stays. A 6 in. down-take pipe in the centre of the column offers a hidden outlet for the roof rain-water, thus doing away with the necessity of the usual unsightly rain-water pipes cutting through the façade from top to bottom as would otherwise be the case. The column loads are carried into a reinforced concrete foundation, which distributes the weight into a lime concrete base below.

Large reinforced lintels rest upon the columns and carry a heavy wall and floor load, the maximum of which is five tons per lineal foot. These lintels are reinforced against shearing stresses by means of bent bars, and top bars are used to provide for negative bending moments. Concrete in the proportion of one part of cement to six parts aggregate was used throughout.

The foundation stone for this building was laid in February 1916 and the building was opened by Lord Ronaldshay in February of this year. The architect to whose designs and under whose supervision the work was carried out was Mr. T. S. Gregson, A.R.I.B.A., of Messrs. Gregson, Batley and King, Bombay.

ANNUAL GENERAL MEETING.

The following is a short abstract from the Annual Report of the Concrete Institute presented at its ninth Annual General Meeting, which was held on May 9th, 1918.—ED.

A SUMMARY OF THE REPORT OF THE COUNCIL.

THE first part of the report deals with the Institute's membership, which at the end of April, 1918, numbered 981. The finances of the Institute are then briefly referred to, and a list of the meetings held during the session is given.

Award of the Institute Bronze Medal.—As the result of a ballot among members of Council, the bronze medal for the best paper read in 1916–17 Session was awarded to Mr. Robert N. Sinclair, for his Paper entitled "Southampton Docks; Re-modelling of an old Dry-Dock."

Scientific Research.—The Research on Concrete Aggregates which is being carried out under the direction of the Institute has made decided advance in 1917 in spite of the great difficulty in obtaining qualified research assistants, and seven provincial laboratories, viz., Birmingham University, Bradford Technical College, University College, Cork, University College, Dublin, Edinburgh University, Manchester Municipal School of Technology and Salford Royal Technical Institute, have commenced work by collecting aggregates on which to carry out experiments. Four of them, Birmingham, Cork, Dublin and Salford, have made concrete specimens with these aggregates, and some of these have been tested. The Institute has to thank several firms who have supplied cement for this research, and also Messrs. Butler and Stanger, who have kindly carried out tests upon it.

The Institute, through its Science Committee, has at every meeting carefully considered points arising under the scheme, and on January 4th of this year a Joint Meeting of the Science Committee and those engaged and interested in the Research was held at the Institute, many useful matters being carefully threshed out. It was decided that a useful development of the movement might take the form of a list of aggregates throughout the United Kingdom, with their distribution, nature, properties, quantities available and prices quotable, together with further supplementary information. Arrangements have been made to obtain these particulars from various authorities.

L.C.C. (General Powers) Act, 1909, and Steel Frame Buildings. The Conference which was convened by the District Surveyors' Association to consider the interpretation of the London County Council (General Powers) Act of 1909 with reference to Steel-frame buildings, and on which the Institute is represented, held regular meetings during 1917, and its Report will be published shortly.

High-Tension Steels in Reinforced Concrete Work. A sub-committee was appointed during 1917 by the Science Committee to consider the question of the use of high-tension steels in reinforced concrete work, the reference being "to formulate a scheme for testing high-tension steels for submission to the British Standards Committee." The following were appointed to serve on this sub-committee—Mr. J. F Butler, Mr. R. H. H. Stanger, Mr. B. Taylor, Mr. R. W. Vawdrey, and Mr. T. A. Watson. Mr. H. Kempton Dyson, in his capacity of Honorary Secretary *pro tem.* to the Institute, was also asked to serve on this sub-committee, and at its first meeting, held on December 13th, 1917, he was elected Chairman and Honorary Secretary by unanimous vote. Invitations to act on the Committee were subsequently extended to representatives of certain firms interested in the question, resulting in the further appointment of Mr. H. R. White as representative of the United States Steel Products Company.

Committees Appointed.—The Committees appointed by the Council for the Session were as follows:

THE FINANCE AND GENERAL PURPOSES COMMITTEE.

Chairman, Mr. Charles F. Marsh; Vice-Chairman, Mr. H. J. Tingle; Ordinary Members—Prof. Henry Adams, Messrs. E. Fiander Etchells, J. E. Franck, H. D. Searles-Wood, Sir Henry Tanner, Messrs. E. P. Wells, G. C. Workman, M. E. Yeatman; *ex-officio*—The President, and Chairmen of Standing Committees.

THE SCIENCE STANDING COMMITTEE.

Chairman, Dr. J. S. Owens; Vice-Chairman, Mr. H. K. G. Bamber; Hon. Secretary, Mr. Ewart S. Andrews; Hon. Secretary, Research Committee, Dr. Oscar Faber; Ordinary Members—Prof. Henry Adams, Prof. T. Hudson Beare, Mr. D. B. Butler, Colonel J. D. Cormack, Messrs. E. Fiander Etchells, J. E. Franck, H. C. Johnson, Charles F. Marsh, W. G. Perkins, A. R. Sage, H. D. Searles-Wood, R. H. Harry Stanger, R. W. Vawdrey, E. P. Wells, F. E. Wentworth-Sheilds, M. E. Yeatman.

THE REINFORCED CONCRETE PRACTICE STANDING COMMITTEE.

Chairman, Mr. G. C. Workman; Vice-Chairman and Hon. Secretary, Mr. R. W. Vawdrey; Ordinary Members—Prof. Henry Adams, Messrs. Ewart S. Andrews, H. K. G. Bamber, P. J. Black, Mr. D. B. Butler, Dr. Oscar Faber, Major J. Petrie, Mr. F. Purton, Major Lewis H. Rugg, Messrs. A. R. Sage A. Alban H. Scott, Archibald Scott, H. D. Searles-Wood, T. B. Shore, B. Taylor, J. M. Theobald T. A. Watson, E. P. Wells, M. E. Yeatman; *ex-officio*, Mr. F. E. Wentworth-Sheilds.

THE PARLIAMENTARY STANDING COMMITTEE.

Chairman, Mr. J. E. Franck; Vice-Chairman, Mr. Osborn C. Hills; Hon. Secretary, Mr. Percy J. Black; Ordinary Members—Prof. Henry Adams, Messrs. W. E. A. Brown, E. Fiander Etchells, W. G. Perkins, Edwin O. Sachs, L. Serraillier, E. P. Wells; *ex-officio*, Mr. F. E. Wentworth-Sheilds.

New Members of Council.—The members of Council chosen to retire under the rules of the Institute were as follows:—Mr. Osborn C. Hills, Major H. Rogers, and Major Lewis H. Rugg, who were not eligible for re-election.

THE WORK OF THE SUB-COMMITTEES.

Science Standing Committee.—The work of this Committee during the past year has chiefly been concerned with the details of the research scheme above referred to. In addition the Committee has considered the suggested amendment of the London Building Acts and Building Bylaws generally, and it is hoped that something will be done in the matter in conjunction with other Societies. The Committee has also advised the Engineering Standards Committee at the request of the latter in respect to the use of special steels for reinforced concrete.

Reinforced Concrete Practice Standing Committee.—This Committee has completed the report entitled "Recommendations to Inspectors, Clerks of Works and Foremen concerning the execution of reinforced concrete work." It has now taken in hand the consideration of the very important matter of the use of reinforced concrete as a substitute in articles hitherto made of timber. In this connection a fairly comprehensive list of such articles has been drawn up and is being submitted to a large list of firms, who are being invited to state which of these articles they are prepared both to design and make. Eventually the information obtained will be embodied in tabulated form, and will be placed at the disposal of the Board of Trade.

THE ANNUAL GENERAL MEETING.

The ninth annual general meeting of the Concrete Institute was held at Denison House, Vauxhall Bridge Road, on Thursday, May 9th, Mr. F. E. Wentworth-Sheilds M.Inst.C.E., presiding.

DISCUSSION.

THE PRESIDENT thought the members of the Institute would agree that this was a satisfactory Report. Their membership had only fallen off very slightly, which he thought, considering the war circumstances, might be regarded as a very satisfactory feature. A number of new members had joined, otherwise the loss of membership would have been greater. The finances too were very satisfactory. They had had seven very interesting papers, all of which had excited a great deal of interest and, considering war circumstances, been very well attended and discussed. The Report gave some particulars of the Research Work which the Institute was carrying on This Research was primarily to investigate the properties of various concrete aggregates which were to be obtained in the United Kingdom and to get information about those aggregates which would be of the very greatest possible use to engineers, architects, builders, and everybody connected with the building trades and professions. They were also organising a questionnaire which would bring together a great deal of useful information about these various aggregates which were to be obtained in this country, so that it would be possible when this information was obtained for anyone to find out easily what aggregates were to be obtained in any particular neighbourhood. They were getting out a list, which he thought would be extremely useful, of articles in which concrete and reinforced concrete could be advantageously substituted for timber, so as to meet the difficulty of timber shortage.

Election of Council.—THE SECRETARY (Mr. Percy L. Marks) reported that the scrutineers had found that the following gentlemen had been elected to fill the vacancies on the Council:—Messrs. H. K. Dyson, R. W. Vawdrey, H. J. Tingle, F. Purton and A. Alban H. Scott.

The Award of Bronze.—THE PRESIDENT announced that the medal for the best paper read last year had been awarded to Mr. Robert M. Sinclair for his paper on " The Southampton Docks: Remodelling of a Dry Dock." Mr. Sinclair was unable to be present that evening as he was engaged on urgent war work. He had written, however, to say that he very much appreciated the award.

ELECTION OF PRESIDENT.

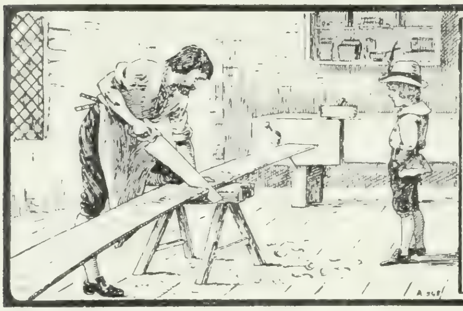
THE PRESIDENT announced that the last item was to him a very pleasant one, namely, to instal their new President-Elect, Mr. H. D. Searles-Wood, F.R.I.B.A. It had been a great satisfaction to them all that Mr. Searles-Wood had been elected, and though they all knew his name and his long connection with the Concrete Institute, there were few of them, except those who had worked with him on the Council, who knew how much time and trouble he had devoted to its interests. He was a man who worked hard for the Concrete Institute and no doubt he would carry on the good work which it had done and would preserve its best traditions.

THE PRESIDENT then vacated the Chair and it was taken by the new President.

MR. LUCIEN SERRAILLIER proposed a vote of thanks to the retiring President for his conduct of the affairs of the Institute for the past year, which was carried by acclamation.

After a short acknowledgment by Mr. Wentworth-Sheilds, the meeting terminated.

Following upon the Annual Meeting, a very interesting Paper was read by Mr. A. Alban H. Scott on " Reinforced Concrete Ships." To this Paper we shall make reference in our next issue.



A PRE-CAST UNIT SYSTEM REINFORCED CONCRETE CONSTRUCTION.

We present herewith a few notes and details of a system of pre-cast unit reinforced concrete as designed by Mr. L. W. Hargreaves. In presenting these notes we would mention that at the moment pre-cast concrete is becoming increasingly popular for certain types of buildings and it has certain advantages more particularly at the present time, namely, (1) A saving of timber is effected, as only few forms are required; (2) the work can be cast under cover, regardless of the weather; and (3) the erection is very rapid once the sections are moulded, and the casting of the concrete can be proceeded with while the excavation and general site work is being done.—ED.

MANY types of reinforced concrete construction adaptable for the erection of light buildings, especially domestic work, have from time to time been used; some have been fairly successful, while others have failed completely, chiefly on account of excessive cost combined with the slowness in erection. The following drawings show Mr. Hargreaves's system, which he claims has been worked out on thoroughly practical lines. The following are the advantages claimed for the system presented herewith :—

The construction is light, fire-resisting, and, above all, absolutely a monolith after erection.

The wall itself is hollow, measuring 6 in. from outside to in, the thickness of concrete being 1 in. The wall is pre-cast in sections of uniform dimensions, and is reinforced with expanded metal, which projects beyond each side.

Two of these sections together form the wall. These are placed at regular intervals on the prepared concrete foundation, and thus a series of wall sections with 6 in. spaces between is obtained. These spaces are poured with concrete, in which is embedded a light reinforcement. The only form-work required on the work is two boards extending from top of foundation to bottom of first floor.

These forms are secured by bolts (in paper tubes) which are withdrawn after column is sufficiently set. On completion of one story these forms are ready for the next story.

The expanded metal, which extends beyond sides of wall section, runs into column, thus binding the whole structure together.

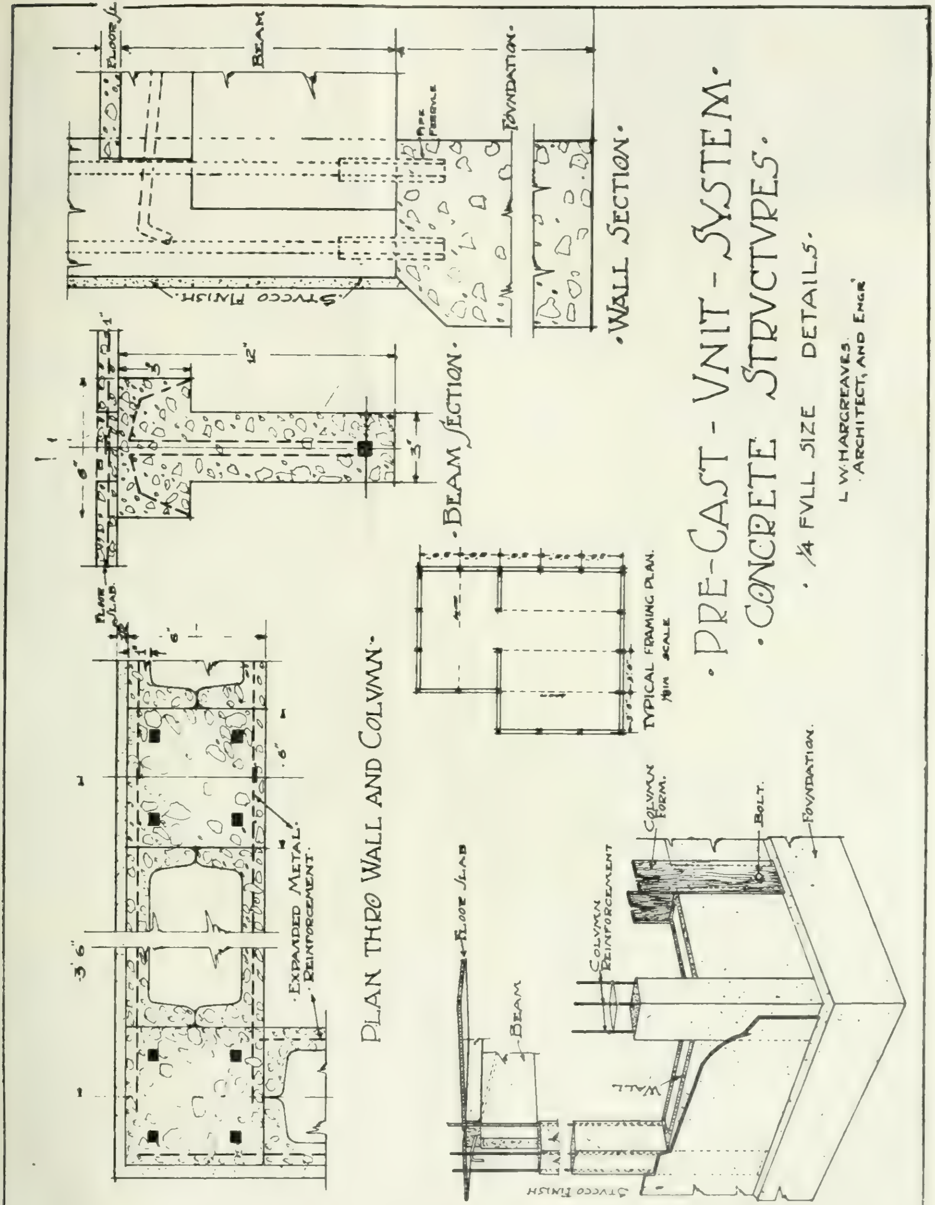
The concrete floor-beams are also pre-cast, and light floor slabs are laid directly on them; the whole bonded together as for columns and wall sections, and thus all loads are carried on wall columns.

This practically describes the system of construction here under review, which is stated to be a quick, strong, and economical method.

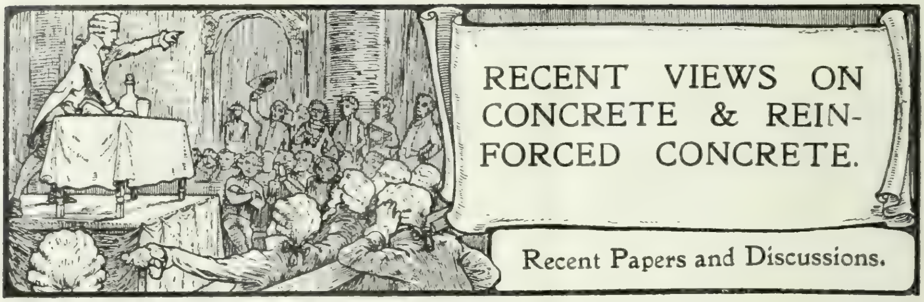
The moulds required in the casting shop are few in number and the sections are light and easily handled.

It may be added that the size of building is unlimited, additional sections simply being added. All loads are carried on direct bearing to foundation.

The methods of floor finish wall coverings are numerous, one adopted by the author being a good grade of cork-lino. glued directly to concrete floor, on



which loose rugs may be placed. Interior plastered, with exterior stucco or other approved finish; the finished structure being artistic, fire-resisting, economical in cost, warm in winter, cool in summer, and structurally correct.



RECENT VIEWS ON CONCRETE & REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

REINFORCED CONCRETE SHIPS.

By T. J. GUERITTE, Ing.E.C.P., M.Soc.Ing.Civ. (France), Councillor of the French Board of Trade.

The following is an abstract of a Paper read recently at a meeting of the North East Coast Institution of Engineers and Shipbuilders.

To judge by the surprise evinced in the daily papers when the first reports were published a few months ago of the great impetus given by the war to reinforced concrete shipbuilding activities, one might have imagined that there was something startlingly new in the idea, and much nonsense was printed at the time, under big headlines. And still the last few years have merely seen the development of activities dating from many years back. It is, in fact, a curious coincidence that it was the Author's privilege to deliver a paper entitled "Reinforced Concrete as Applied to Floating Structures," in the year 1908, before one of the Newcastle building trades associations, the matter of which formed the basis of many of the articles which were published on the subject during the last few months. The conclusions of that paper ran as follows :—"The particulars and illustrations given seem sufficient to indicate that reinforced concrete has to be taken into account as a ship building material, owing to its small initial cost and the absence of upkeep. The author is far from thinking that super-dreadnoughts are likely to be built in reinforced concrete, at any rate for the present, but in smaller and commercial craft and for special purposes, he is convinced that it will be used more and more. The question of weight is not so paramount as it may seem at first when to the weight of the hull is added that of all fittings and cargo, which remain the same both for reinforced concrete and for steel ships." The recent strides made in this mode of construction seem to justify those prognostics.

1.—MATERIAL OF CONSTRUCTION.

This is evidently a fundamental question and we shall consider in turn the two components of a reinforced concrete hull, viz., concrete and steel.

(*a*) The *concrete* employed must be non-porous, so as to prevent leaking and the steel being attacked by sea water, it must also be strong so as to resist heavy compressive stresses to which, in parts, it is submitted, and it should be as light as possible. The last named condition is unfortunately difficult to fulfil at the same time as the other two, and the latter are of greater importance. Light *aggregates* such as pumice stone, ashes, coke breeze, which are used in land work for making light concrete, are too porous; they would absorb a large weight of water and would give too weak a concrete; they cannot be utilised for ships. Clean shingle, of a flinty nature, is a suitable material, and would give a concrete slightly lighter in weight than crushed granite or whinstone. Gravel originating from sandstone must be subject to careful scrutiny before being allowed for ship construction as it is sometimes of a somewhat porous and friable nature, and might prove a source of weakness both as regards porosity and crushing strength. Crushed granite and, generally speaking, crushed stone of a hard and impervious nature, are perhaps to be given the preference, notwithstanding their somewhat heavier weight. The same physical qualities are essential for the *sand.* Of the *cement* itself, little need be said, years of experience have proved that if it is up to British Standard Specification it will prove suitable for sea work.

With such constituents and it being understood that fresh water only should be used both for making the concrete and washing the aggregate if necessary, a suitable concrete will be made if proper proportions are adopted and the materials are properly mixed. In determining proportions great care should be taken that the aggregate be properly graded, that is, it should contain stones of various sizes, the smaller ones helping to fill the voids between the larger, and the same applies to the sand, which should be a mixture of sharp particles and of finer sand going down almost to dust. The proportions of voids both in the aggregate and in the sand should be carefully determined and there should be a good excess of cement paste over the quantity strictly required to fill the voids in the sand, and similarly a good excess of mortar (*i.e.,* sand and cement paste) over that required to fill the voids in the aggregate. As previously mentioned crushed stone will be used often as an aggregate, and it so happens, that it contains as a rule a considerably greater proportion of voids than shingle, and this may result in porousness in the concrete unless proper attention is paid.

From practical considerations the Author does not deem it advisable to allow for a lesser thickness of concrete than 3 in. for the sides and bottom of a vessel, except in special circumstances and however much one might like to see it reduced so as to lighten the structure. The figure of 2·8 in. is mentioned as a minimum in the preliminary rules for reinforced concrete ships issued by the Danish Government, but except for very small craft 3 in. will prove in practice to be the minimum. The scantlings of frames, stringers, etc., are also reduced as much as possible owing to the same desire to reduce the weight, and the thickness may be taken at 2½ in. and even less in some cases, but great care will have to be exercised to insure proper covering of the bars by the concrete and proper bond between them. It is therefore necessary to use an aggregate of small size, which will be worked easily in so restricted a space and among a comparatively great number of steel rods. Some engineers went as far as to suggest the total abandonment of aggregate, and the replacement of concrete by a mere sand and cement mortar. But the method has been proved to be unsatisfactory in ordinary reinforced concrete work and the same would apply to ship construction. A happy medium is to be recommended, and the Author's firm have ultimately adopted the following mixture for their designs :—

Aggregate, being a well graded mixture of stones from ⅝ in. size down to ¼ in. and free from sand, 27 cu. ft.

Sand, from ⅛ in. downward, the grains being also of well graded sizes, 13½ cu. ft.

Cement, 8½ cwt.

Such a concrete may be termed a 1·6 : 2 : 4 concrete.

The above proportions apply as long as the percentage of voids in the aggregate does not exceed 50 per cent. If it exceeds 50 per cent. a corresponding quantity of sand and cement is added.

It has been suggested by various engineers that a much poorer concrete might be used with safety, say a 1 : 2 : 4 or 1·2 : 2 : 4 concrete, if a good rich rendering were applied later on the external surface of the sides and bottom. But such a rendering would be extremely difficult to make properly, especially when nearing the bow and stern, and with the hard wear and tear to which ships are submitted it would soon come away in patches.

In order to obviate the difficulty of making a proper rendering other engineers have suggested to use a comparatively poor concrete, say 1 : 2 : 4 or 1·2 : 2 : 4 for the inner 2 or 3 in. of the walls and bottom and to place carefully at the same time in the mould a rich mortar (1 of cement and 1 of sand) to form the external inch. The Author's experience leads him to deprecate the juxtaposition of two concretes of so different a richness in cement, and unless supervision of the most constant and strict nature is exercised during erection he doubts the efficacy of the method. All told, it seems decidedly better to adopt a uniformly rich mixture, such as menioned above, which will give a very good face to the concrete when the moulds are struck off, prove quite impervious, afford a high crushing strength, and be easily worked into the moulds.

(*b*) *Steel.*—We turn now to the other component element of the structure, viz., the steel. The general tendency in reinforced concrete practice has been to utilise as reinforcing material mild steel in the form of ordinary round bars, with an ultimate tensile strength of from 28 to 32 tons per sq. in., an elastic limit varying from 30,000 to 40,000 lb. per sq. in., and an elongation of at least 20 per cent. on a length of eight times the diameter. Such steel was used in the construction of most of the numerous river and canal barges and pontoons built in reinforced concrete during the last 15 years, and it was natural to look to the same material again, when great impetus was given lately to the construction of sea craft in reinforced concrete by the difficulty of procuring all the steel plates required for commercial craft. Mild steel was therefore used and will be used in many ships notwithstanding the difficulty one meets in obtaining it at present. Shell discard steel has been put forward as a substitute, mostly with the object of avoiding the use of mild steel, seeing that it is more easily obtainable than the latter at present, but not owing to its special physical properties. For the present, apparently, Lloyd's Register are not prepared to sanction its use.

It is a question, however, whether the disadvantages attaching to the use of shell discard steel, if one looks at the question from the usual standpoint of steel ship construction, would not be more than compensated by certain advantages it would present from a reinforced concrete point of view. These advantages are somewhat similar to those attaching to the use of a special quality of steel, which the Author's firm, after careful consideration of the matter during the last two years, are now specifying for reinforced concrete ship construction. It may be stated at the outset that the problems of reinforced concrete construction as applied to naval artchitecture are very different from its problems as applied to land work. Firstly, and for obvious reasons, it is desirable to reduce the weight of the hull, and consequently of all the scantlings, as much as ever possible, consistent with good work. It becomes, therefore, of great interest to use for the reinforcement steel possessing a higher elastic limit than mild steel, the elastic limit being an all important factor in reinforced concrete work. Not only does this obviously tend to reduce the weight of steel required and consequently the weight of the hull, but also the same cover of concrete over the reinforcing rods can be maintained while reducing the thickness of the members by the same amount as the diameters of the high elastic limit steel rods are smaller than those of the mild steel bars which would otherwise be used, thus securing an indirect but very important saving in the weight of the hull.

A second point which deserves very careful consideration is that of the transmission of the stresses in the steel from bar to bar. As is well known, in reinforced concrete construction the bars are not tied together, nor welded, nor connected by coupling boxes (except in very special circumstances). Stresses are transmitted from bar to bar through the agency of the adhesion grip of the concrete surrounding them, the bars overlapping each other. Their ends are usually fishtailed or hooked, with a view to helping further the adhesion. In ordinary reinforced concrete work the mass of concrete surrounding the rods is comparatively large, and there is ample room for overlapping of the rods and for the hooks or fishtails, so that most of the experts in reinforced concrete consider it quite unnecessary to use bars with mechanical bond. In ship construction, as has been previously stated, scantlings are reduced to a minimum, and the bars being very much closer together real difficulty is experienced in finding room for overlaps of the length required if ordinary round rods are used, and also for hooks, especially in longitudinal members. The problem is serious, and experiments carried out in France last year upon a river barge of 400 tons deadweight, which was purposely tested until rupture under load in the dry proved the ultimate failure to be due to the slipping of the longitudinal rods, consequent upon the insufficiency of overlapping. It must be added that the overlaps were in fact considerably shorter than sound design would have required. But the indication given must not be neglected. It therefore becomes useful for reinforced concrete ship construction to adopt bars which present a greater adhesive power than ordinary round bars. Tests have proved that certain bars are obtainable which have a grip 60 per cent. greater than that of ordinary rounds; their use will obviously reduce the amount of overlapping otherwise required. But such greater adhesion should not be obtained by the addition of sharp projections or ribs on the bars which might have a tendency to be the starting point of minute cracks in the concrete, and which, in addition, are useless from the point of view of the main stresses. In other words, the bond should be continuous, and should not entail an additional weight of steel. To sum up the question of the steel, the Author has found the nearest approach to what he considers the ideal steel reinforcement for shipbuilding work in bars manufactured from mild steel in accordance with Britih Standard Specification for structural steel, but which, owing to their special shape and the physical treatment they receive after rolling, acquire an elastic limit of over 50,000 lb. per sq. in., present a satisfactory and continuous bond without sharp indentations or projections, and remain capable of cold bending round a bar of 1½ times their diameter without injury.

Shell discard steel, if of a somewhat unequal quality, possesses at least one of the desiderata, viz., high elastic limit. Dangerous as may be its use in the shape of girders or, more generally, structural steelwork, where stresses may be said to be extremely localised, it is felt that its use in the shape of numerous rods of small diameter scattered throughout the mass of a reinforced concrete structure does not present the same danger. It seems, therefore, that the question of its employment might be left open for further consideration, and the experience gained from the behaviour of the numerous reinforced concrete works in which it was used since 1915 will be of great help in that direction.

2.—SYSTEMS OF CONSTRUCTION.

Having examined the constituting materials, one may now attempt to reply to the query: "What are the various systems of construction"? They seem to fall under two headings—Plastered ships; moulded ships.

(*a*) *Plastered Ships.*—The first cost of a mould in which to cast a reinforced concrete ship, in a similar way as is generally done for ordinary reinforced concrete work, is high, and it was natural that one should attempt to avoid using one. Many of the numerous river barges and pontoons built in Italy since 1902 consisted mostly of a steel meshwork set to shape and plastered on both sides with cement mortar, very much as a ceiling of a room is plastered on a metallic lathing, and the method proved successful for small craft which are never strained heavily. Small motor boats or canoes have been built similarly in various countries, including, of course, the small pioneer rowing boat built in France in 1849 by Lambot. When one comes, however, to heavier craft, and particularly seagoing craft, meshwork is found to be not practical for the arrangement of the main steel reinforcement; and what is more important, plaster work of that kind does not give a concrete sufficiently strong to meet the stresses imposed upon it. The claims of the "cement gun" in that respect do not appear as yet to be justified. The Author is convinced that for all vessels of large size the plastering method has to give way to the method of moulding and casting.

(*b*) *Moulded Ships.*—(1) In the first place, there should be a warning against the practice recommended by one or two American contractors of building a sort of rigid metallic work—lattice girders forming the skeleton of all the frames, and also the skeleton of the sides, and encasing this metallic framework in concrete. The advantages claimed are simplicity and quickness of construction. The Author considers that there would be no appreciable saving in time, and there are very serious defects inherent to the system. All reinforced concrete experts agree that the ideal design in reinforced concrete is that in which the reinforcing rods are individually as small as possible and as numerous as is practicable, so that the stresses be distributed to the extreme possible limit throughout the mass of reinforced concrete. The result is best attained by the use of small rods and links. If, however, the steel is concentrated in parts of the mass instead of being distributed throughout, the work thus obtained loses those peculiarities just referred to; the concrete will not lend its properties to the steel and borrow some from the latter in so complete a manner, and *vice versa.* In particular, the large cracks so characteristic of ordinary concrete work, and unknown in reinforced concrete, would tend to appear, and this would be a very serious defect in ships. The work would also lose the resilience and elasticity which is so striking a character of reinforced concrete. Another point is that a rigid framework of that kind, instead of being made of round bars, would require flat bars and small angles; in fact, structural steelwork of the very kind that is most in demand to-day. It would also require the employment of steelworkers of the very kind one wishes at the present time not to draw upon, seeing that all the steelwork would have to be punched, bolted and riveted. Moreover, experience has shown that such a method of reinforcement is more wasteful in steel by 15 to 20 per cent. It has also been found in practice that in reinforced concrete work it is most advisable to avoid any sharp angles or corners in the steelwork, all such angles being potential starting points of cracks; and that concrete adheres less easily to comparatively large and flat surfaces such as presented by angle bars than to ordinary round bars. It may also be added that if, in order to avoid riveting, an attempt is made to use bolts, as the bolt holes will be of greater diameter than the bolts (so as to facilitate fitting up) there will remain throughout the framework an immense number of small recesses to which concrete will not have access; the steelwork will therefore not receive in those points the protection against corrosion which the concrete should afford it, and such points will be potential starting points of corrosion.

(2) The Norwegian method of casting the boats upside down, launching them in that position, and letting the hull right itself in the water, has been profusely described and illustrated in the daily papers and magazines. The reason for that unusual procedure is stated to be a desire to avoid the use of double shuttering. But, as far as the deck and bottom are concerned, there is no more need for a double shuttering in the usual method than in the upside down one, and as regards the sides there is as much need for it in one as in the other.

(3) In the construction of river barges in France, the desire to reduce the cost of shuttering has led to certain constructors experimenting with pre-cast wall plates of the required dimensions to fill the rectangular spaces between frames and stringers. The frames

and stringers are cast *in situ*, and the wall plates set in position between them so as to be incorporated into the structure during their concreting, the bond being given by the ends of the reinforcing bars of the plates, which protrude all round. Although the results were said to be satisfactory (at first, in any case) it is interesting to note that when the same contractors built larger river craft (600 and 1,000 tons deadweight) they abandoned the slab principle and reverted to casting *in situ*.

(4) Another " system " is that in which timber moulds are dispensed with for the walls by using two sheets of metal lathing between which the concrete is poured. Some of it works through the mesh and forms knobs upon the two outer surfaces, which knobs in turn form anchorage for plastering coats added later on. The objection against the use of plastering coats required to finish the surface has been stated before. Another drawback of this method is that concrete poured between two resilient sheets of meshing cannot be rammed or punned properly, and in consequence it is impossible to obtain a good, strong and impervious concrete. The advocates of this method, in fact, are said to recommend the addition of a waterproof coating, which the Author has no doubt would indeed prove very necessary with such a method.

(5) Reverting now to the normal and usual method of construction, it can hardly be divided into systems; the general principles underlying all the designs are the same, and it is merely the experience and skill of designers which may differentiate the various types adopted. In that respect the Author is fully in accord with the remarks made by Mr. A. T. Wall in the *Engineering Supplement* of the *Times* regarding the absolute necessity for close co-operation in the design of ships between naval architects and reinforced concrete experts.

3.—SPEED OF CONSTRUCTION.

One of these claims is a great speed of construction.

In the construction of a large number of 250 horse-power tugs now being built in France the author was able to satisfy himself that two weeks were sufficient to erect the moulds (for repeat tugs; the erection of the first mould took somewhat longer) and place the steel in position. The process of concreting was occasionally carried out in forty-eight hours. All told, it is safe to say that in normal working the yard referred to completes a hull in three weeks. The tugs take water broadside on, and an average of three weeks is allowed for maturing. With the restricted amount of labour at present available the said yard can turn out one of these tugs every week, but from explanations given to the Author by the yard's manager it is certain that two tugs could be completed every week in normal times. In another place the Author has seen in what was four months before a bare field two 1,000 ton deadweight barges ready for launching and several others following closely. Barges of that kind, or again, the hulls of small cargo steamers of 1,000 tons deadweight, may easily be turned out and launched at the rate of one every ten weeks from each slip in a well organised yard. For obvious reasons it is impossible at the present time to give precise figures as to the actual speed of construction of bigger reinforced concrete craft. The time required for the fitting of machinery, etc., would be practically identical for such ships and for steel ships. It will be understood that from three to five weeks has to be added to allow for the maturing of the concrete. In ordinary land work one considers generally that a test load may be imposed upon a new floor five or six weeks after its completion. But the concrete used in that case is not so rich in cement as for ships, and the richer the concrete the quicker the required strength is attained. It might be possible to utilise that period for partly fitting up the ship instead of waiting until she is afloat, so that the maturing period would not be lost altogether.

4.—EASE AND SPEED OF REPAIRS.

This question of speed in construction leads us to another important consideration—viz., the ease and speed with which reinforced concrete ships may be repaired. Reinforcd concrete has been proved to withstand damage to a remarkable extent. One need only refer briefly to its excellent behaviour during the earthquakes, during subsidence of foundations, etc. This is due to the monolithic character of the work and its great cohesion.

Such local damage as may occur in reinforced concrete ships will be most easily repaired, the hole being blocked up by providing a small timber shuttering and filling the hole with new concrete, after having added, if need be, a few strengthening bars. By using a very rich mixture of concrete, the patch will be able to stand the water pressure in a couple of days or even less, and if need be, one may not remove the shuttering before putting to sea again, for further safety. Such a repair may even be carried out under water. Cementing or concreting repairs to quay walls or jetties under water are by no means processes unknown to civil engineers.

In December last the Author had the good fortune (if he may put it that way) to inspect a 1,000-ton barge which a couple of days previously had suffered damage during a faulty launching; it had been repaired as explained above, and was then afloat and in excellent condition. Several instances of damage to river or canal barges in use abroad have been recorded, pointing all to the same conclusion, and all investigators seem agreed that repairs to reinforced concrete ships will be quicker and much cheaper than to steel vessels. Alterations to the design in course of erection, or while the ship is in service, are quite easy. The Author has witnessed in France a fairly sweeping alteration in the position and arrangement of hatchways and companions in a vessel nearing completion, which confirms this statement.

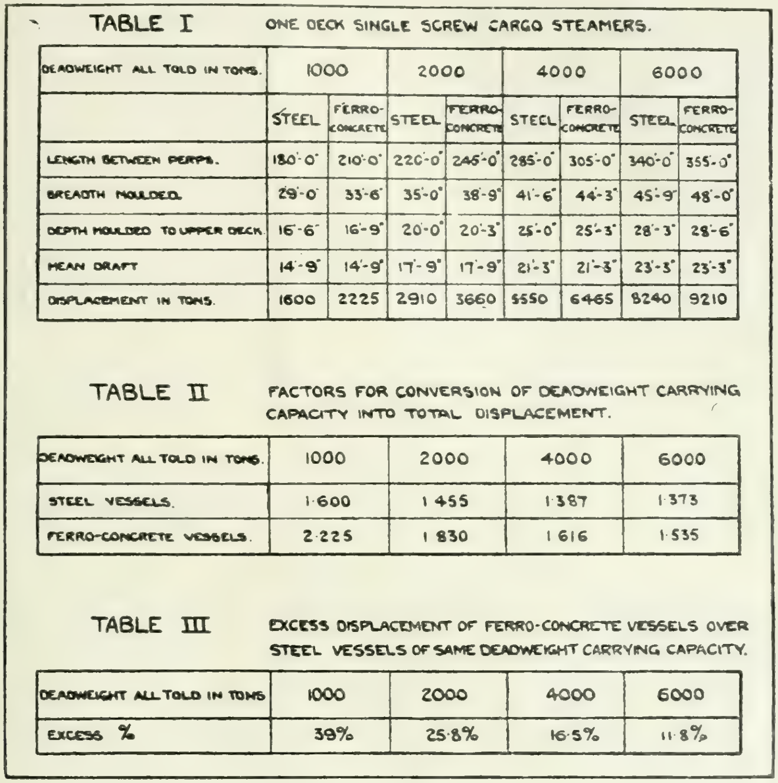


TABLE I ONE DECK SINGLE SCREW CARGO STEAMERS.

DEADWEIGHT ALL TOLD IN TONS.	1000		2000		4000		6000	
	STEEL	FERRO-CONCRETE	STEEL	FERRO-CONCRETE	STEEL	FERRO-CONCRETE	STEEL	FERRO-CONCRETE
LENGTH BETWEEN PERPS.	180'-0"	210'-0"	220'-0"	246'-0"	285'-0"	305'-0"	340'-0"	355'-0"
BREADTH MOULDED.	29'-0"	33'-6"	35'-0"	38'-9"	41'-6"	44'-3"	45'-9"	48'-0"
DEPTH MOULDED TO UPPER DECK.	16'-6"	16'-9"	20'-0"	20'-3"	25'-0"	25'-3"	28'-3"	28'-6"
MEAN DRAFT	14'-9"	14'-9"	17'-9"	17'-9"	21'-3"	21'-3"	23'-3"	23'-3"
DISPLACEMENT IN TONS.	1600	2225	2910	3660	5550	6465	8240	9210

TABLE II FACTORS FOR CONVERSION OF DEADWEIGHT CARRYING CAPACITY INTO TOTAL DISPLACEMENT.

DEADWEIGHT ALL TOLD IN TONS.	1000	2000	4000	6000
STEEL VESSELS.	1·600	1·455	1·387	1·373
FERRO-CONCRETE VESSELS.	2·225	1·830	1·616	1·535

TABLE III EXCESS DISPLACEMENT OF FERRO-CONCRETE VESSELS OVER STEEL VESSELS OF SAME DEADWEIGHT CARRYING CAPACITY.

DEADWEIGHT ALL TOLD IN TONS	1000	2000	4000	6000
EXCESS %	39%	25·8%	16·5%	11·8%

5.—LASTING QUALITIES OF REINFORCED CONCRETE VESSELS.

Views on that aspect of the question are difficult to express, for the reason that experience has not yet been obtained regarding their behavious at sea over long periods. Most probably steel shipbuilders found themselves in the same predicament when steel was first put forward as a substitute for timber. Let us also proceed by inference. We know that reinforced concrete on land is a most permanent material, requiring no upkeep, no painting, and increasing in strength with age. We know that the same applies to reinforced concrete sea work or tidal work, jetties, quays, etc., when properly designed and carried out. There may have been a few cases (very few indeed in proportion to the number of successful works) in which defects developed. But in those cases the defect can always be traced to causes which do not affect the principle of reinforced concrete, and could have been avoided by taking due care. Local examples being always of special interest, one may properly refer here to a reinforced concrete jetty built in 1901 at the C.W.S. works, Dunston-on-Tyne, with a rise and fall of tide of 15 feet, and which is in absolutely perfect condition, although it is now submitted to much greater shocks than was anticipated owing to the increased tonnage of vessels accommodated.

We know, further, that reinforced concrete vessels for river or canal or harbour work have stood the test of time very well indeed; comprehensive lists of such vessels have been printed so often lately that it is unnecessary to repeat them.

On the other hand, we know that seacraft are submitted to much more severe strains, and this is where doubt may arise. To overcome the difficulties which confront reinforced concrete seacraft, one must first of all realise them fully, and recognise the inherent drawbacks of the material. It is then comparatively easy to devise means for removing the disabilities. That there will be failures cannot be doubted. Most of them will arise from imperfect understanding of the effect of combined stresses. But the experience already at our disposal is sufficient to show that some of the difficulties encountered can be overcome by more careful designing, and there are good grounds for assuming that the reinforced concrete vessels which it is now proposed to build up to a certain size will have the necessary lasting qualities. The question now arises as to what is the limiting size of reinforced concrete ships, but before trying to give a tentative reply to the query it is necessary to face one of the great defects of reinforced concrete vessels, viz., their weight.

6.—WEIGHT OF REINFORCED CONCRETE VESSELS.

It is so obvious that reinforced concrete vessels are heavier than steel ones that there is no need to explain why. The important point is to make a comparison between vessels of the two classes and of same deadweight carrying capacity. The designs of vessels upwards of 1,000 tons deadweight prepared by the Author's firm comprise one deck single-screw cargo vessels of 1,000, 2,000, 4,000 and 6,000 tons deadweight, and the comparison will be limited to those. It must be stated that the full detailed working plans for the larger units are not quite completed as yet, so that slight alterations in the figures here below given are possible.

In the following tables the figures referring to the steel vessels have been kindly prepared by Mr. R. Cole and Mr. H. Burgess, of Messrs. Sir W. G. Armstrong, Whitworth and Co., Ltd., the design of the reinforced concrete vessels has been prepared in collaboration with Mr. T. G. Owens Thurston, of Messrs. Vickers, Ltd., and to them the Author wishes to tender here his best thanks.

The above Table I. allows one to compare at a glance the main characteristics of the vessels.

From the figures in that table another, Table II., has been prepared, which gives the factor for converting deadweight carrying capacity into total displacement, both for the steel and the reinforced concrete vessels figuring in Table I.

7.—COST OF REINFORCED CONCRETE SHIPS.

The saving which can be effected by reinforced concrete in a certain class of vessel is due partly to the saving in steel, partly to the fact that no heavy plant is required for reinforced concrete work, and partly to the fact that the bulk of the labour employed need not be skilled, and is therefore cheaper. But if the last two factors remain the same whatever the size of the vessel, the first is a variable one. To start with, it must be stated that the saving in steel is not as great as was claimed at first; a saving of 80 per cent. or even more as has been mentioned occasionally seems quite out of the question. Nevertheless the saving exists and in some cases exceeds 50 or 55 per cent. which is not at all negligible. And in that respect it is as well when comparing figures to note that in reinforced concrete there is no waste of steel in the process of construction, whereas it seems a recognised fact the weight of steel required for building a steel ship is about 10 per cent. greater than that of the steel which is finally embodied in the structure owing to waste in cuts of plates, angles, rivet holes, etc. As far as stresses go steel is not used very economically for steel ships of small tonnage, but it receives a better utilisation when the tonnage grows. By way of illustration, taking as units the stresses per sq. in. on the upper deck and on the bottom plating respectively for steel cargo vessels of 1,000 tons deadweight it may be assumed that the stresses in bigger vessels would approximately be greater in the ratio shown in the following Table IV. :—

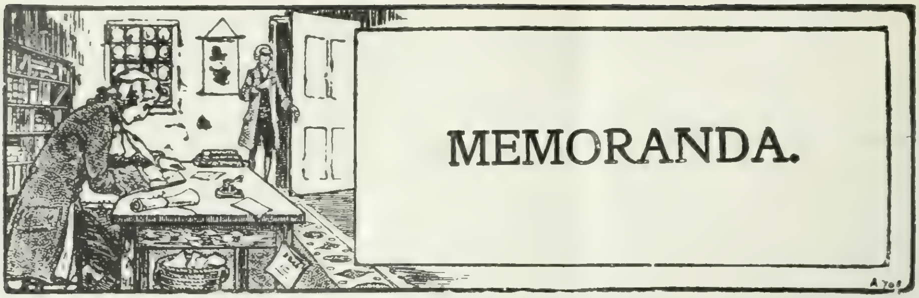
TABLE IV.—RATIO OF INCREASE OF STRESS TONS PER SQ. IN.

Deadweight in Tons.	1.000.	2,000.	3,000.	4,000.	5,000.	6,000.
On upper deck	1	1·18	1·33	1·44	1·54	1·64
Bottom plating	1	1·22	1·40	1·58	1·75	1·94

It will be seen that steel vessels have to meet the same difficulty as reinforced concrete vessels in the case of small tonnage, viz., a bad utilisation of the full strength of the constituent materials. Whereas, however. in the case of reinforced concrete it is the concrete which is badly utilised (as far as its potential strength is concerned), in steel vessels it is the steel. In both cases the drawback gradually disappears when the tonnage increases.

A much better utilisation of the steel takes place in reinforced concrete ships of small tonnage, utilisation which cannot be improved upon very much when tonnage increases. It would seem that the important saving in steel resulting from the adoption of reinforced concrete for ships of small tonnage remains a fairly constant percentage up to, say, 3,000 tons deadweight, but in the light of present designing that for larger units it would become gradually smaller.

It is most difficult to give an accurate comparison of the prices for steel and reinforced concrete ships. The question is so beclouded by considerations of many kinds that it has been questioned whether the undeniable advantage which reinforced concrete offers to-day in this respect will remain when normal times return. The Author feels unable to give precise indications which actual experience may alone procure. But it seems fair to say that on a pre-war basis one may estimate that the cost of the reinforced concrete hull is about 70 per cent. of the cost of the steel hull of same deadweight carrying capacity in the case of small tonnage, the saving becoming somewhat less important for bigger units. As against this one may set up the fact that the cost of machinery and outfit for concrete vessels is approximately 5 per cent. dearer than it is for steel vessels.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

The Chemical Industry in France.—A Chemical Industry Society has been formed in France under the title "Société de Chimie Industrielle" for the purpose of bringing Science and Industry into close touch with one another throughout the country, and the Administrative Council includes the most eminent industrial authorities on chemical questions in France. Every branch of Chemical Science and Industry will be represented. The objects of the new Society are briefly: (1) To assist the extension of the chemical industry in all its domains; (2) to group and bring into touch with each other the chiefs of industry, scientists, engineers, chemists, etc., who are interested in one branch or another of chemical science; and lastly to contribute to the progress of the chemical industry from an economic as well as from the scientific point of view.

The Society will issue a monthly journal which will record not only the activities of France in this important branch of industry, but will also give particulars of research work carried out in other countries. The section devoted to cements, limes and constructional materials is under the able direction of Monsieur Candlot.

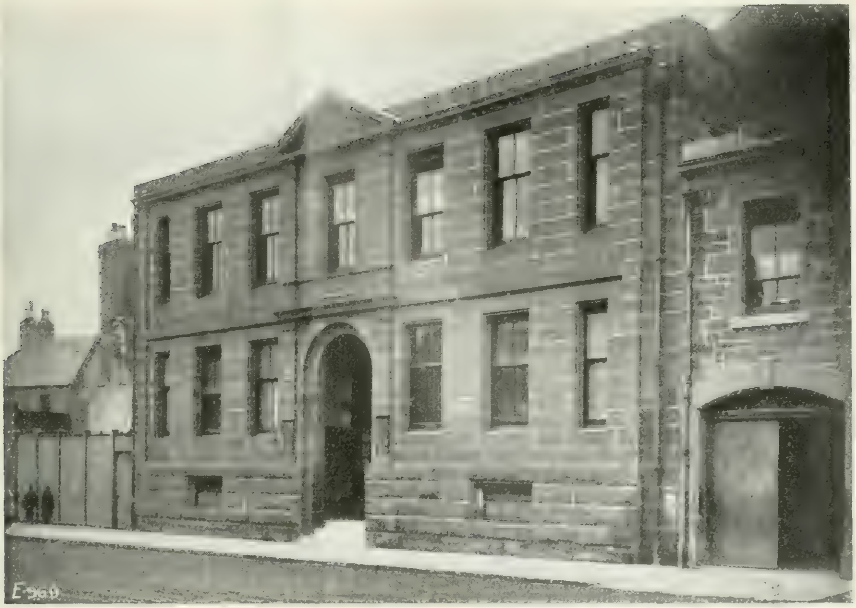
Swimming Baths at Arbroath.—The following short description of some public swimming baths at Arbroath is an interesting example of the use of reinforced concrete for this kind of building. The question of erecting public swimming baths in Arbroath had been under discussion for a very long time, but it was only just prior to the outbreak of war that a scheme was definitely decided upon and carried out by the Arbroath Municipality.

Competitive plans for the proposed baths were advertised for and the first prize was awarded to the plans submitted to Mr. Hugh Gavin, architect, Arbroath. The building is of reinforced concrete throughout. The planning of the building is arranged in such a way as to allow for future extension of the slipper baths, the piping being all ready for any such addition. In the conditions of the competition for plans emphasis was laid on the necessity of keeping carefully in view the need of oversight and control by a limited staff. Accordingly, in the plans selected, the slipper baths and swimming pond are on the same level as the ticket office, so that all these can be superintended by one attendant. Ten slipper baths have been provided. There is also suitable store and lavatory accommodation. On the first floor there is a platform gallery overlooking the swimming pond. The dimensions of the pond are 75 ft. by 30 ft. and it is amply lighted and ventilated from a glazed cupola which runs along the whole length of the roof. Forty dressing boxes have been provided on the north and south sides of the swimming pond, and over the dressing boxes are galleries for spectators.

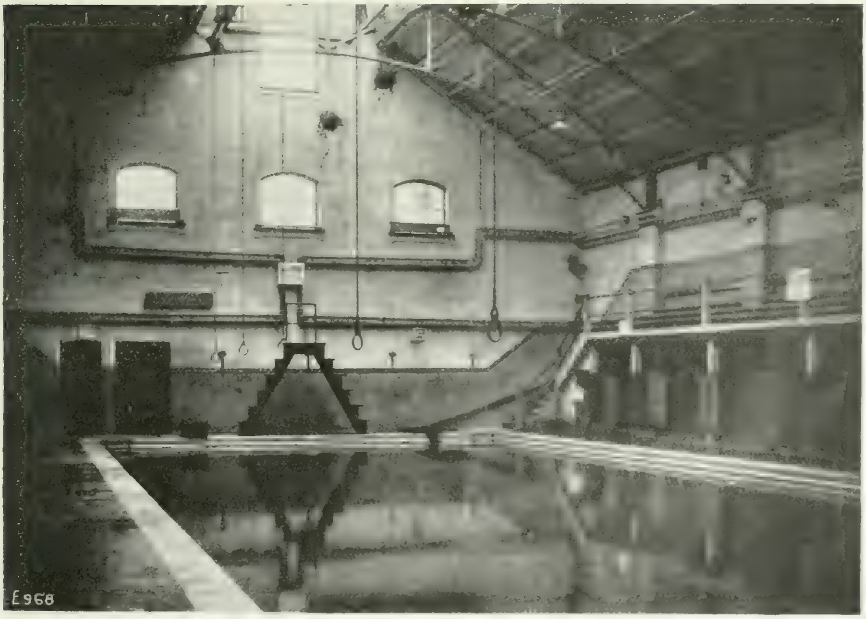
The laundry, engine room and boiler house are situated on the west side of the building.

The reinforced concrete construction work was carried out by the Allen Construction Co., of Glasgow, and nearly the whole of the cement was supplied by Mr. James Cables, Arbroath, agent for the Associated Portland Cement Manufacturers, Ltd. Our illustrations show an interior and exterior view of the premises.

Tests of Reinforced Concrete Pit Props.—Some very interesting tests were undertaken recently at the Manchester University on some concrete pit props made by The Lilleshall Co., Ltd., of Salop. The props were reinforced on the "Keedon" system and were up to 6 ft. long with $\frac{3}{8}$ in. steel rods as reinforcement passing through



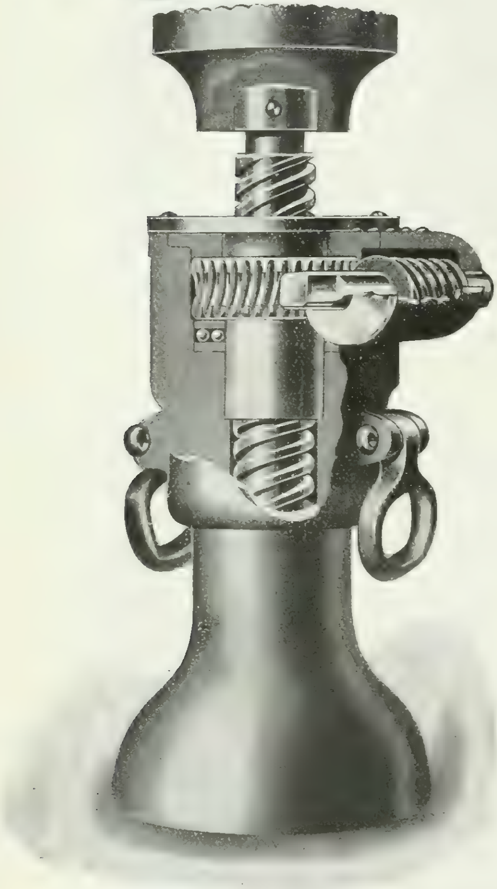
Exterior View.



Interior View.

Reinforced Concrete Swimming Baths, Arbroath.

The BRITISH STEEL PILING Co



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corner hoops in triangular steel frames and fixed at intervals. There were also props $7\frac{1}{2}$ ft. long similarly reinforced. Some 20 concrete props were tested and the results are shown in the following table :—

No.	Broke at, tons.	No.	Broke at, tons.
1	26	11	$20\frac{1}{2}$
2	$25\frac{1}{2}$	12	$25\frac{1}{2}$
3	37	13	$30\frac{1}{2}$
4	$41\frac{1}{2}$	14	23
5	$42\frac{1}{2}$	15	$30\frac{1}{2}$
6	$19\frac{1}{2}$	16	30
7	23	17	33
8	19	18	31
9	$19\frac{1}{2}$	19	$29\frac{1}{2}$
10	$17\frac{1}{2}$	20	25

A number of wood props of varying lengths and about 5 in. in diameter were also tested and subjected to a load of from $14\frac{1}{2}$ to 30 tons. Only two English larch props withstood 30 tons. It is stated that the wood props in nearly every case broke in the middle.

An ordinary prop was also tested for side pressure. This broke at 6,500 lb. This weight was kept on the prop, which continued to bend, but did not collapse. A 7 ft. Welsh larch bar broke at 2,700 lb. A 10 ft. concrete bar broke at 15,100 lb., and had a deflection of $6\frac{5}{8}$ in., and was still considered safe, although the concrete was badly cracked. A great feature about the concrete props was that they broke or crushed at one end, only damaging about 9 in. to 12 in. in length. This was cut off, and the prop again put in the testing machine, and in every case the prop which was retested came out stronger than the original prop. The ends of one prop were sawn off twice, making three props in all, and there was no reason to believe otherwise that all the props could be sawn in a similar way. This is a great factor in the use of concrete pit props underground, because they can be used over again after one has been broken, without any deterioration in strength.

India.—Recently the Indian mail brought news of the death of one of the pioneers in reinforced concrete construction, as also of the later cement manufacturing industry in India.

We refer to the late John James Marsland, who died on February 25th last.

He was responsible for bringing into being the well-known Bombay firm of Messrs. Marsland, Price & Co., Ltd., specialists in reinforced concrete construction and constructional engineers. The firm started business in 1899, and has carried out a large and varied amount of work in different parts of India, the latest being concrete ships.

In 1908 the firm became a joint stock company with a capital of six lakhs, and is at present under the able management of Mr. George T. Mawson, who, notwithstanding "the war," reports considerable work in hand.

It is a rule with the company to employ only their own staff of qualified workmen in carrying out reinforced concrete work under skilled supervision, and to detailed designs also prepared by their own experienced engineers.

This method is commendable, for clients are assured of sound work at the minimum expenditure in materials and labour.

Engineers and others in India requiring structures in reinforced concrete would be well advised to approach this company, which has the very necessary long practical experience in this ever expanding class of construction.

CORRESPONDENCE.

Concrete Simplified.

To the Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

SIR,—I have read your April number with great interest, and I should like to point out to the writer of the article entitled "Concrete Simplified" that in my opinion (and I feel sure my ideas will be endorsed by most of your readers) it is unwise to recommend the use of "boiler ashes" as a suitable aggregate for floor or roof concrete, especially for the latter, for the good reason that cracks and expansion arise from the chemical action set up by the presence of sulphur in "boiler ashes."

As regards watertight concrete roofs without asphalt, my experience as a concretor and asphalter is that if instead of boiler ashes as an aggregate three parts of clean machine-broken brick bats and three parts of coarse sand or fine gravel to one part of Portland cement were used, and finished on top with fine gravel and cement, three to one, and mixed with a waterproofing compound, will make a safe watertight roof without asphalt.

In floor work I should use the "boiler ashes" you recommend simply for the reason that you can nail boards to them, but make provision for expansion by inserting wood wedges along the walls and drawing them out, thus leaving a space after the concrete is set. Yours faithfully, JOSEPH B. JOHNSON.

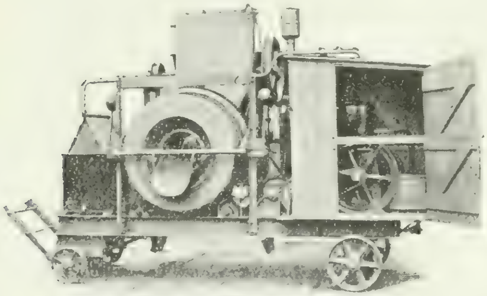
P.S.—Temperature cracks can be effectually treated with a wash of "Ironite," and flat roofs thus made watertight.

TRADE NOTE.

Water in Cellars.—Every winter the cellar of Tanhouse Farm, Ipsley, has been flooded to a depth of 18 in. to 24 in. The walls have been made bone dry with waterproofed cement but the floor has been left until the dry season owing to the permanent flow of water. By waiting until the summer when the flood subsides the expense of continual pumping will be obviated, and it is then proposed to cover the floor with Pudloed concrete.

PUBLICATION.

The Empire Municipal Directory and Year Book 1918.—This publication forms a most useful guide and book for reference purposes for all interested in municipal affairs. The Directory of Local Authorities (Section I.) is most complete and comprehensive. Section II. deals with Roads and Road-making and contains useful notes regarding all the various materials employed in road construction. A portion of the section refers to reinforced concrete road systems, and briefly refers to the experimental roads laid in Kent. There are other notes regarding concrete and concrete construction which will be found in Section IV. entitled, "Plain and Reinforced Concrete and Cement." Other sections deal with Lighting and Heating, Water Supply, Sewerage and Sewage Disposal, Fire Prevention, and Town Planning. A special feature is the Municipal War Legislation Section comprising all the Statutes, Orders and Regulations enacted or issued since August 1914. The volume is considerably enlarged since last year's issue and is published by the Proprietors of *Municipal Engineering* and *The Sanitary Record*, 8, Bream's Buildings, Chancery Lane, E.C.4, price 5s. net (post free, 5s. 6d.).



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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIII., No. 7. LONDON, JULY, 1918.

EDITORIAL NOTES.

THE MINOR USES OF CONCRETE.

SINCE the dearth of timber made itself felt this journal has consistently pressed the uses of concrete for the many minor purposes for which timber is usually employed, but is not essentially or necessarily even the most economical material to use. We have shown by illustration and otherwise the innumerable uses to which concrete can be put for everyday purposes.

When three years of the War had elapsed, the Concrete Institute also commenced to formulate a list of the objects to which concrete can be usefully applied, but we have not yet seen any formal communication thereon, nor have we observed any publicity given by the Institute to this subject.

Under the circumstances we ask whether it should not be one of the primary objects of the Timber Controller not only to control and regulate the supply of the available timber, but more systematically to discourage its use and encourage the employment of concrete as a substitute.

We are, of course, aware of the Cabinet instruction that has been issued to all Government Departments that the employment of timber is to be limited, and that, as far as possible, substitutes, such as concrete, be specified. Some Departments are quite loyal to this Cabinet instruction ; others, either owing to neglect or for reasons other than technical, continue the use of timber where it is not essential.

The War Office, in particular in its Home Commands, is a primary delinquent in this direction, but it is not the only one. Municipalities have entirely failed to realise the advisability of systematically substituting other materials for timber ; in the county councils, the urban district councils, an insistent wastage of timber still prevails. Surely the time has arrived to prohibit the use of timber for unnecessary purposes.

Has not the time come for the Timber Controller to issue literature, both of a technical and popular character, in the form of circulars, notices, and posters, that may serve as a guide to the public and to their professional advisers as to what may be done to limit the uses of timber ?

Though mainly concerned in the advantages of employing concrete for the reason that the primary aggregate for concrete is practically everywhere available throughout the country without transportation, and the proportion of cement needful as a binding material is comparatively small and also readily obtainable throughout the country, we do not wish to be so narrow-minded as to lose sight of the fact that there are other materials besides concrete which can in places be readily substituted for timber. But whether this be brick or asbestos composites, we hold that there is nothing more economical, and which requires less expenditure by way of maintenance, than concrete where substitutes have to be provided.

This journal appeals to the technical reader in particular, and it has not failed to indicate the substitutes for timber suitable for minor purposes. Its publication, *Concrete Cottages, Small Garages, and Farm Buildings*, published recently, also gives a very considerable amount of information in this direction useful to the technical professions, the estate owner, the farmer, and the public generally. Organisations such as the Concrete Utilities Bureau have issued most useful pamphlets on specific forms of construction to which concrete is applicable in these times. But we hold that where national interests are at stake, and where so much tonnage is required to bring in the timber used, it is high time that the Government as such, and preferably the Timber Controller's Department, should act boldly and prohibit the use of timber in certain directions, whilst plainly encouraging the employment of other materials.

PUBLISHERS' NOTE.

Owing to the continued increase in the cost of paper and of production, we find ourselves now compelled to raise the price of our journal to 1*s.* 6*d. per copy* (*annual subscription* 18*s.*).

Owing to the conditions at present prevailing, we had only two courses open to us—namely, either to reduce the size of the journal or to increase its price; and after careful consideration the latter course has been decided upon.

* * * * * *

We would remind readers that owing to the new Order in Council the bookstalls no longer keep supplies of the journal for chance purchasers, and that copies have to be ordered in advance at the booksellers or bookstalls, or subscribed to at the Publishers' Office, 4 Catherine Street, Aldwych, London, W.C.2.

SEGREGATION AREA, SHOWING GOVERNMENT POLICE COMMISSIONER'S BUNGALOW, KOFORIDUA, GOLD COAST COLONY.

SOME NOTES ON BUILDING IN WEST AFRICA: WITH SPECIAL REFERENCE TO THE USE OF CONCRETE

By H. G. HOLT, A.R.I.B.A.

Part II.

The following notes with regard to building materials imported to West Africa, sanitation in connection with buildings, and further details and views of the buildings of the Bank of British West Africa, Ltd., will no doubt be of interest.—ED.

IMPORTED BUILDING MATERIALS.

PORTLAND cement takes the chief place of importance in the list of materials sent out to West Africa for building purposes, and it is largely used all over the coast. Structural steel is also wholly imported. Door and window fittings, locks, door furniture, etc., are made of brass or bronze. On the sea coast iron perishes rapidly owing to the humidity and salt in the air. Glass, paints, and asbestos sheeting of various kinds are also imported. Pressed asbestos slates have been largely used, but do not appear to be wholly satisfactory as a roof covering; they absorb a certain amount of moisture, and are apt to curl up at the corners with the heat when laid diamond-wise. Corrugated iron roofing is preferred in many cases for durability and weatherproof qualities, but certainly the appearance of good-class buildings is not improved by the cheap, shoddy look which a corrugated sheet roof always gives. The cost of freight has always to be carefully borne in mind, and there is nothing gained by exporting cheap poor-class fittings, as the freight is the same as on a better-class and more lasting article. The problem of a satisfactory roof covering is one of the chiefest in connection with West African building. Welsh slates have been tried, but it has been discovered that the natives do not get into the knack of holing and fixing these properly; breakage in transit is also a serious drawback to the use of slates. The French import quantities of Marseilles red roofing tiles into the French Ivory Coast, and these make a handsome and durable roof, but they are very expensive. Probably cement and sand tiles, waterproofed with Pudlo or some other waterproofing composition, form as good a means of roofing a decent class building as any method tried hitherto. Such tiles were used on the roof of the staff bungalow of the Bank of British West Africa, Limited, at Accra (Gold Coast Colony). Reports indicate that during last rainy season, which was one of the worst in recent years, the tiles proved quite serviceable and weatherproof. The laying of the tiles, apart from the care which must be exercised in their manufacture, naturally plays a great part in their weatherproof or other qualities.

At " K " Hill, Seccondee, a large bungalow was erected some time ago for the Bank of British West Africa, Ltd., by Messrs. H. Greene & Co., of Liverpool, Freetown, and Lagos, and the interesting photograph in *Fig.* 9 illustrating this shows the building in course of construction. Note the thin scaffolding reminiscent of native Indian scaffolding. The building was erected with concrete blocks and mass concrete in parts, and was planned by Mr. J. H. Garner. *Figs.* 10 and 11 show details of the Bank building at Seccondee previously described.

A few views are illustrated of various buildings at Koforidua, formerly known as Komfrodua, an inland town in the cocoa district of the Gold Coast, on the Accra railway. These illustrations are interesting as showing the development of the West African township: a general view of the main street is shown in *Fig.* 12; again note the motor car ! The Government public offices are shown in *Fig.* 13, comprising district engineers' and treasurers' offices. The police commissioner's bungalow is shown in Title headpiece, which is a view of the Government segregation area. To the right may be seen the temporary hut, left standing from early construction days.

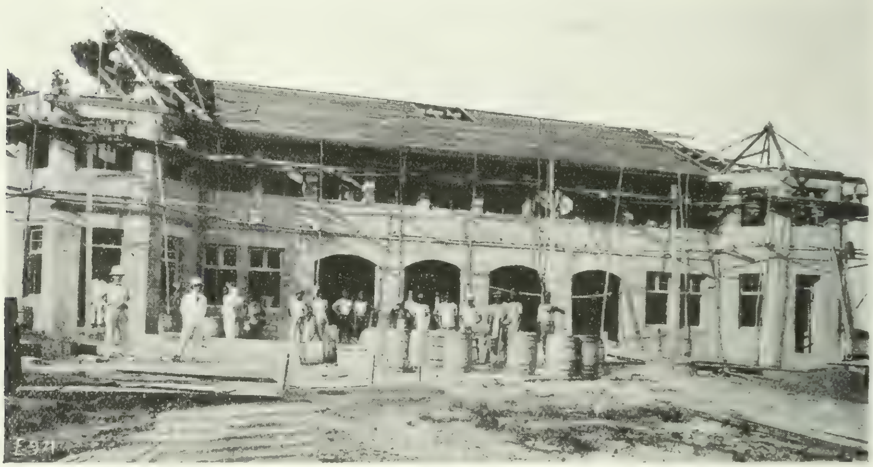


FIG. 9. CONCRETE BLOCK BUNGALOW IN COURSE OF CONSTRUCTION AT " K " HILL, SECCONDEE.

The Bank building at Coomassie, on the Gold Coast, is shown in *Fig.* 14, and one of the trading firms' premises adjoining. The buildings are part brick and part concrete, and both were among the first substantial erections put up in Coomassie.

These notes regarding West African building would be incomplete without some reference to

SANITATION.

Good sanitation is essential if health is to be maintained, and especially is this the case in tropical countries, where special difficulties and dangers inimical to health are encountered. There is no doubt that in West Africa one of the worst causes of trouble is the mosquito, and to prevent the breeding of mosquitoes is one of the main points to which attention is constantly devoted. Some very valuable researches have been made, and much useful information has been published by the Yellow Fever Commission (West Africa), from the main points of which I quote the following as being of particular importance as a guide in connection with the arrangement of buildings and their fitting from a sanitation point of view:

"Eggs are laid on fallen leaves lying in water holes."

"Cooling acts as a stimulus to the hatching of eggs." . . .

"The larvæ period is passed in four days under favourable, and up to 70 under unfavourable circumstances."

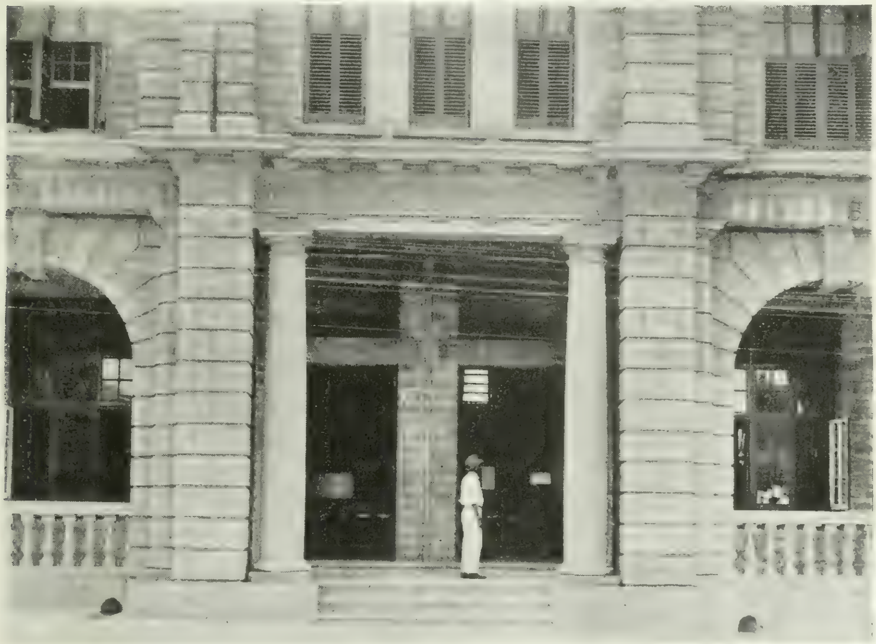


Fig. 10. Bank of British West Africa, Ltd., Seccondee. Main Entrance.

"The larger larvæ of *S. Fasciata* consume the smaller ones." . . .

"There is an apparent association between the speed of larval growth and the development of bacteria."

"*Ants* proved *deadly foes* of caged mosquitoes." . . .

"*Salt water* speedily kills larvæ, but does not destroy the pupæ." . . .

"*Salt water for flushing culverts and gutters and watering roads might prove very beneficial.*" . . .

"*Emulsions of soft soap and petroleum are more effective larvicides than when used separately, and with naphtha added kill all larvæ and pupæ at a strength of* 1 *in* 20,000."

"*Kitchen and boys' quarters are most often chosen for deposit of eggs.*"

"Well covered, cleanly *cisterns require covers of specially small mesh wire* *gauze, not less than* 18 *by* 18 *gauge*, as eggs may be washed in from gutters during rain. Adult mosquitoes of normal size do not pass a 16 by 16 gauge, but if dwarfed by scarcity of food undoubtedly could do so, and a mesh of not less than 18 by 18 is essential for safety."

Public water supply is not generally obtainable. Lagos has a public water service, so has Abeokuta, in Nigeria, and both these towns are supplied with electric lighting service, though that at Abeokuta is suspended at present. Public water supplies have also been provided at Accra and Seccondee in the Gold Coast, but at Freetown, the capital of Sierra Leone Colony, there has been a very efficient water supply for a number of years.

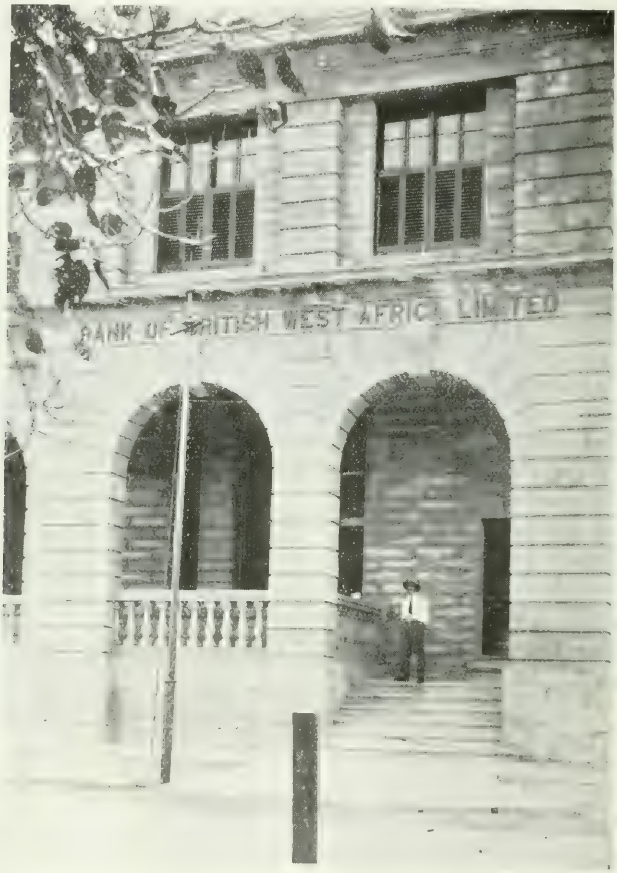


FIG. 11. BANK OF BRITISH WEST AFRICA, LTD., SECCONDEE. MANAGER'S PRIVATE ENTRANCE.

The water supply for domestic purposes is usually collected from the roofs and stored in cisterns, hence the above remarks quoted from the Report. Lighting is generally by kerosene lamps, though acetylene gas lighting has been installed

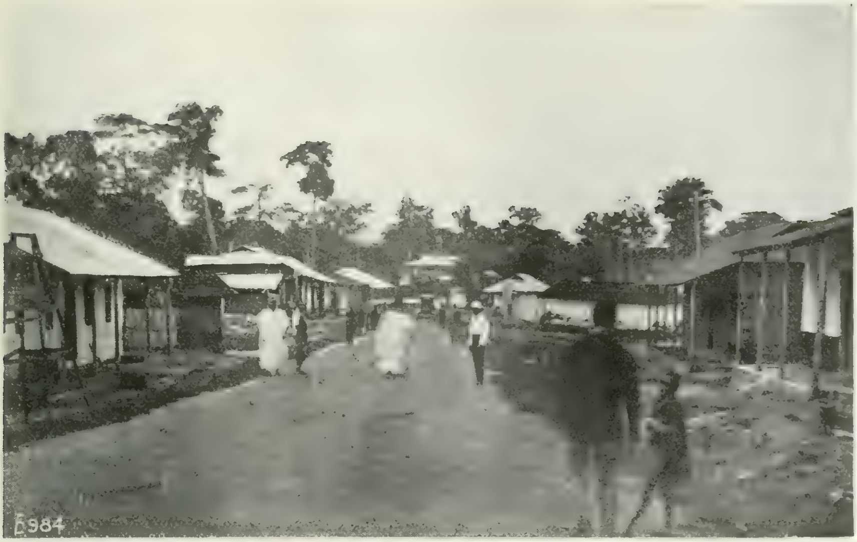


Fig. 12. General View of Main Street, Koforidua.

Fig. 13. Government Offices at Koforidua.

at several buildings belonging to the Bank of British West Africa and one or two of the trading firms have also adopted it. This form of lighting has been very successful, and it can be attended to by a native boy after instruction.

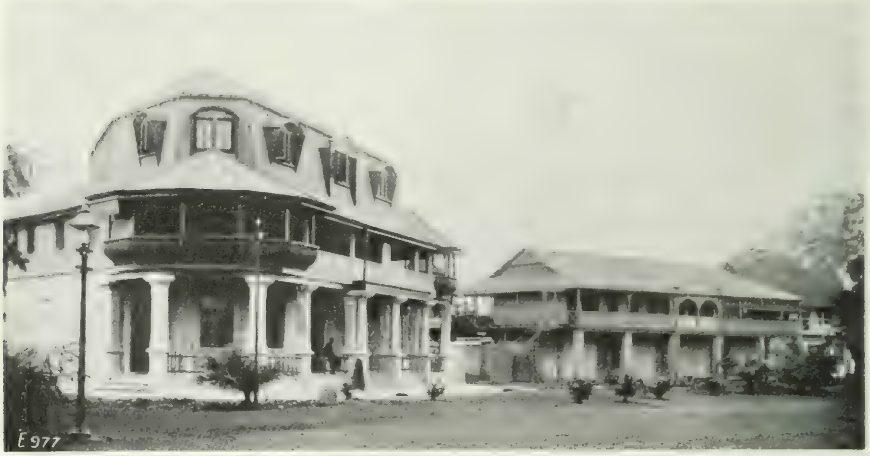
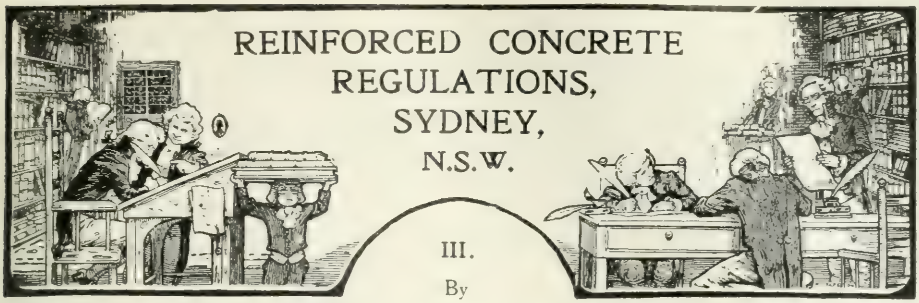


FIG. 14. BANK BUILDING AT COOMASSIE IN FOREGROUND, PARTLY CONSTRUCTED OF BRICK AND PARTLY OF CONCRETE; MESSRS. MILLER'S, LTD., PREMISES ADJOINING.



REINFORCED CONCRETE REGULATIONS, SYDNEY, N.S.W.

III.

By

CHARLES F. MARSH, M.Inst.C.E.

(Concluded.)

The first two articles on these Regulations appeared in our May and June issues. —ED.

REGULATIONS 71 to 83 inclusive deal with working stresses and follow the final report of the special committee of the American Society of Civil Engineers.

Regulation 71 states that the effect of impact must be added to the live load (superimposed loading) to produce an equivalent static load, which must be used in all calculation before applying the allowed working stress or proportioning parts; that the working stresses must be taken as percentages of the ultimate strength of the concrete actually used as developed at an age of twenty-eight days in cylinders 8 in. in diameter and 16 in. long, made and stored under laboratory conditions.

This method of obtaining the working stress is much preferable to the arbitrary equations of the London County Council regulations, as it allows advantage to be taken of careful grading of the aggregates.

Clause 71 further gives the following average general strengths, in lbs. per sq. in., for concretes made of the best Portland cement with clean, gritty sand, composed of hard, siliceous grains, free from clay or any animal, vegetable, alkaline, or bituminous matter:

TABLE I.

Aggregate.	1 : 1 : 2	1 : 1·5 : 3	1 : 2 : 4	1 : 2·5 : 5	1 : 3 : 6
	$V=3$	$V=4\frac{1}{2}$	$V=6$	$V=7\frac{1}{2}$	$V=9$
Blue metal and river gravel of the hardest and best quality	3,000	2,500	2,000	1,600	1,300
Ordinary sandstone of good quality .	2,200	1,800	1,500	1,200	1,000
Clinker concrete	800	700	600		

Regulation 72 provides that the concrete in the work must not have less strength than 90 per cent. of the foregoing, when tested as cylinders of the foregoing dimensions and under the foregoing conditions. In this case the working stresses must not exceed the percentages, given under the following regulations, of the figures set out in the above table.

Regulations 73, 74, and 75 state that the compressive working stress must not exceed the following percentages of the actual compressive strength of the concrete.

Bearing.—Such as the bearing of columns upon foundations of concrete where the surface is not less than twice the loaded area, 35 per cent. of the compressive strength of the concrete on the area actually under load.

Axial Compression.—For concentric compression on a plain concrete column, the length of which is not greater than four times the least lateral dimensions, 22·5 per cent. of the compressive strength of the concrete.

Compression in Extreme Fibre.—(*a*) The extreme fibre stress of a beam, calculated on the assumption of a constant modulus of elasticity for concrete under working stress, may be allowed to reach 32·5 per cent. of the compressive strength. (*b*) Adjacent to the support of continuous beams, stresses 15 per cent. higher may be used.

These working stresses give the following values, in lbs. per sq. in., based on the above table of compressive strengths.

TABLE II.

Aggregate.	1 : 1 : 2				1 : 1½ : 3				1 : 2 : 4			
	Bearing.	Axial.	Flexural.		Bearing.	Axial.	Flexural.		Bearing.	Axial.	Flexural.	
			a	*b*			*a*	*b*			*a*	*b*
Blue metal, river gravel, etc. ..	1,050	675	975	1,121	875	562	812	934	700	450	650	747
Ordinary sandstone, etc. ..	770	495	715	822	630	405	565	673	525	337	487	560
Clinker concrete ..	280	180	260	299	245	157	227	261	210	135	195	224

It will be seen that the above values for flexural stresses are considerably higher than those allowed under the London County Council regulations, and especially so in the case of the stronger mixtures than 1 : 2 : 4.

Regulation 76 provides for the allowable maximum shearing stresses to be used as a means of measuring the resistance to diagonal tension, and gives the following values.

(*a*) For beams with horizontal bars only, and with no web reinforcement, 2 per cent. of the compressive strength.

(*b*) For beams with vertical stirrups spaced not more than half the depth of the beam apart, or with longitudinal bars bent up at an angle not greater than 45° or less than 20°, with the axis of the beam, the points of bending being not further apart than three-quarters of the depth of the beam, not to exceed 4·5 per cent. of the compressive strength.

(*c*) For a combination of strirrups and bent-up bars spaced apart not more than half the depth of the beam, 5 per cent. of the compressive strength.

(*d*) In a unit frame consisting of bent-up bars and stirrups rigidly connected to the longitudinal bars the strirrups placed not more than half the *effective depth* of the beam in the case of vertical stirrups and not more than three-quarters the *effective depth* of the beam in the case of inclined members, either with longitudinal bars bent up or nor, 6 per cent. of the compressive strength.

(*e*) Web reinforcement must be designed to carry at least two-thirds of the total vertical shear.

The above percentages on the values in Table I. are as follows, in lbs. per sq. in. :

TABLE III.

Aggregate.	1 : 1 : 2				1 : 1½ : 3				1 : 2 : 4			
	a	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Blue metal, river gravel, etc.	60	135	150	180	50	112	125	150	40	90	100	120
Ordinary sandstone, etc. ..	44	99	110	132	30	81	90	108	30	67	75	90
Clinker concrete	16	35	40	48	14	31	35	42	12	27	30	36

Regulation 77 provides that the total external vertical shear carried by bent up bars shall in no case be considered as resisting a stress greater than 4½ per cent. of the ultimate strength of the standard cylinders tested at an age of twenty-eight days.

Regulation 78 states that the stresses in stirrups and bars bent up at not more than 45° or less than 30° (this should be 20°, see 76 (*b*) above) shall be determined by first finding the portion of the total external shear which may be allowed to the bent-up bars, and this portion subtracted from the total external shear leaves a remainder of which two-thirds must be provided for in the design of the stirrups.

Regulation 79 provides that the safe punching shear stress, when all diagonal tension is provided for, shall not exceed 6 per cent. of the compressive strength. (This gives same values as under columns (*d*) Table III.)

Regulation 80 provides that the bond stress between concrete and plain bars shall be taken at 4 per cent. for drawn wire, 2 per cent. of the compressive stress. For the best type of deformed bar the bond stress may be increased, but must not exceed 5 per cent. of the compressive stress.

These percentages give the following safe stresses: Twice the stresses under columns (*a*), the stresses under columns (*a*), and the stresses under columns (*c*) Table III., respectively.

Regulation 81 provides that the tensile or compressive stress in the steel shall not exceed 16,000 lb. per sq. in., excepting for special steels referred to under Regulation 110, which allows in special cases, by permission of the City Surveyor, stresses up to 18,000 lb. per sq. in., providing the bond stresses do not exceed those specified under regulation 80.

Regulation 82 gives the following values for $m = \frac{E_s}{E_c}$:

TABLE IV.

Ultimate strength of concrete lb. per sq. in.	Not more than 800	Between 800 and 2,200	Between 2,200 and 2,900	Exceeding 2 900
Value of *m*	40	15	12	10

In calculating deflections, neglecting the tension in the concrete, it is provided that the value of *m* shall be taken as 8.

It is questionable whether a variable value for *m* for 1 : 2 : 4 concretes and richer mixtures is necessary, a constant value of 15 being sufficiently accurate.

Regulation 83 provides that the tensile resistance of the concrete is not to be considered in the design of beams or floor slabs.

Regulations 96 to 99 inclusive deal with the spacing of reinforcements.

Regulations 96 and 97 provide that the distance centre to centre of bars must not be less than twice the diameter of the coarse aggregate, plus the diameter of the bar, nor less than three times the diameter of the bars.

Regulation 98 provides that the distance from the centre of a bar to the edge of the concrete is not to be less than one and a half the diameter of the coarse aggregate plus half the diameter of the bar.

This regulation appears to be unnecessary since Regulation 94 deals with the protecting coating of concrete over the bars.

Regulation 99 states that the spacing of the main reinforcing bars of slabs shall not exceed twice the depth of the slab.

Provisions as to columns are dealt with in Regulations 63 to 70 inclusive.

Regulation 63 defines a column as a compression member of a length greater than one-fourth but not greater than fifteen times the least diameter or width. (It would appear that " one-fourth " is an error and should read " four times.")

Regulation 64 provides that the effective diameter of a column must be taken as that within the circle enclosing a spiral, or the square or polygon enclosing the bars or structural shapes within a concrete column : that spirals or hooping shall be considered as increasing the toughness of a column and adding to its ultimate strength, but, as having small effect on its behaviour under stresses within the elastic limit of the material.

Hooping is to be circular, and the ends of bands must be united so as to develop their full strength.

This appears to mean that the ends of hooping bars are to be actually united, but the bending in of the end to the centre of the core and overlapping several windings will secure the same result.

Regulation 65 provides that the core of a hooped column must be straight and concentric, and properly held in place.

Regulation 66 states that no hooped or spiral column is to have a length exceeding ten times its effective diameter.

This regulation appears somewhat restrictive as many hooped columns have been constructed of a much greater relative length without detriment to the safety of the structure.

Regulation 67 provides that longitudinal reinforcement may be considered to add to the compressive resistance of a column by an amount equal to " m " times its area, where $m=\frac{E}{E_c}=15$ for ordinary 1 : 2 : 4 concrete.

Regulation 68 provides for the compressive working stress on columns with various types of binding reinforcement, as follows :

(*a*) If the longitudinal reinforcement is not less than 1 nor more than 4 per cent., and the lateral ties are not less than ¼ in. diameter and spaced apart not less than three-fourths the effective width or diameter, or more than sixteen times the diameter of the longitudinal bar, the allowable stress on the concrete may be 22·5 per cent. of the compressive strength. This stress is the same as for " axial " loading, Table II.

(*b*) With longitudinal reinforcements as above, and with circular spirals not less than 1 per cent. of the volume of the concrete if the length of the column does not exceed ten times the effective diameter, the allowable stress on the concrete may be 50 per cent. higher than that given in (*a*).

The volume of the concrete referred to above is evidently that of the hooped core.

The stresses allowed under (*a*) and (*b*) above are very low.

No spiral hooping is to have a volume less than 1 per cent. of that of the enclosed column, and the clear spacing of the hooping must not exceed one-sixth the diameter of the enclosed column, and preferably not greater than one-tenth, provided that in no case it shall be greater than 2½ in.

(*c*) In square or rectangular columns, there must not be less than four vertical bars ; and in every circular or polygonal column not less than six vertical bars. The diameter of the vertical bars is not to be less than ½ in. or greater than 2 in.

In the above the word " vertical " evidently is intended to mean " longitudinal."

There appears no adequate reason for limiting the diameter of longitudinal bars to 2 in. The same restriction is enforced under the London County Council regulations, and was probably copied from the recommendation of the final report of the Special Committee of the American Society of Civil Engineers.

Regulation 69 states that bending stresses in columns due to eccentric loads are to be provided for by increasing the area of the cross-section, so that the maximum stress does not exceed the values specified.

Regulation 70 is similar to Regulations 110 and 111 of the London County Council and provides that the joints in longitudinal bars must be at or near a floor level or other point of lateral support, and that the overlap of the bars must be at least equal to twenty times the diameter of the upper bar.

Materials are dealt with under Regulations 100 to 114 inclusive.

Regulation 100 provides that all materials shall *not* be of the best quality, and shall be subjected to definite requirements and tests.

It is obvious that the "not" should have been omitted from this regulation.

Regulation 101 deals with cement, which must meet the conditions for slow setting Portland cement of the standard specification of the New South Wales Government.

Regulation 102 provides that the quantity of cement is to be determined by weight and 93¾ lbs. are to be deemed to be equivalent to a cubic foot; three bags or one cask of cement is to be taken as equivalent to 4 cu. ft.

The cement is evidently considered as being packed very tightly, as the usual equivalent for bagged cement is 90 lb. per cu. ft.

Regulation 103 states that great care is to be taken in selecting coarse and fine aggregates, and in mixing them in the necessary proportions to secure maximum density or minimum voids.

Regulation 104 provides that gravel is to be separated into fine and coarse aggregates before proportioning.

Regulation 105 states that the fine aggregate must consist of sand, gravel screenings, or crushed stone, graded from fine to coarse, and passing dry a screen having ¼ in. apertures. Preferably the sand should be composed of hard siliceous grains, but it must be free from clay or any animal, vegetable, alkaline, or bituminous matter. No more than 30 per cent. should pass a sieve having 2,500 meshes per sq. in.

For the purpose of regulations this clause is somewhat indefinite, and the actual wording of the recommendations of the Special Committee appears to have been literally followed. "Preferably" and "should pass" are neither definite nor binding.

Regulation 106 provides for tests of any sand or fine aggregate being made on 3 to 1 mixtures compared with similar mixtures of standard sand (Emu Plains sand) passing a sieve having 400 meshes per sq. in., and retained on a sieve having 900 meshes to the sq. in. If the strength of the mortar of the sand to be used falls below 85 per cent. of the strength of the mortar made with standard sand, more cement must be added in order to secure the desired strength.

Regulation 107 states that the coarse aggregate must consist of gravel or crushed stone retained on a screen of ¼ in. mesh and graded from the smallest to the largest particles. The stone is to be gravel, blue metal, sandstone or other stone, hard, clean, and durable, free from clay, animal, vegetable, bituminous, or other deleterious substances. All dust, soft, flat, or elongated particles are to be excluded. The largest particles to be used are not to be greater than that which will form a homogeneous concrete of sluggish consistency that will pass through and completely surround the reinforcing bars, and fill all parts of the form.

Vitrified, boiler, furnace, or destructor clinker must be composed of hard, clean, vitreous clinker free from sulphides, unburnt carbonaceous matter or ashes. Concrete made from this material may be used for constructing floor slabs not exceeding 12 ft. span, and for partitions, but is not to be used for any other work without the permission of the City Building Surveyor.

The lower screening limit of ¼ in. would exclude dust or ashes without need for a further definite ruling.

The upper limit of size is somewhat vague, and it is not clear how the size of the coarse aggregate is to be gauged by the consistency of the finished concrete. The elimination of the soft, flat, or elongated particles would be a difficult matter and necessitate hand sorting.

This regulation seems to have rather slavishly followed the recommendations of the American Society of Civil Engineers, but to have somehow omitted to use the last portion of the paragraph in the American Society of Civil Engineers' recommendations dealing with the maximum size for the coarse aggregate, which reads as follows :

" The maximum size of particles is variously determined for different types of construction, from that which will pass a ½ in. ring to that which will pass a 1½ in. ring."

For reinforced concrete it is generally agreed that the maximum size should pass a ¾ in. ring or square mesh.

The American Society of Civil Engineers' recommendations either state that the screen used must have circular holes or that the material should pass a ring. The Sydney regulations merely state the size of the mesh without defining it as circular or square.

Regulation 108 states that the water used shall be free from oil, acid, alkali, or organic matter.

Regulation 109 states that the steel must conform generally with the British standard specification for structural steel used in girders and bridges, that it must be made by the open-hearth process, and have a tensile strength of 55,000 lb. to 65,000 lb. per sq. in., a yield point equal to one-half the tensile strength, and an elongation measured on a length of 8 in., equal in per cent. to 1,500,000 divided by the tensile strength, and further that the steel must bend cold through 180° without signs of fracture round a pin of a diameter equal and twice the thickness of the bar.

The detailed requirements vary considerably from the British standard specification, and it is, therefore, difficult to see why this specification is mentioned.

The British specification gives for the tensile strength 62,720 lb. to 73,920 lb. per sq. in., the yield point not being defined.

The elongation given in the Sydney regulations is that adopted by the special Committee on Reinforced Concrete of the American Society of Civil Engineers, as is also the bending test. The bending test of the British specification is to an internal radius not greater than one and a half times the thickness of the test piece.

The stress at yield point required under the Sydney regulations is too definite, and should be not less than one-half the tensile strength instead of being absolutely fixed at half the tensile strength.

One-half the tensile strength is a very low limit for the yield point. The American specification permits a limit not less than 60 per cent. of the tensile strength.

Regulation 110 allows special steels, which show superior physical properties to be used, with the permission of the City Building Surveyor, and a higher stress to be allowed in proportion to the higher yield point developed, but not exceeding 18,000 lb. per sq. in. Provided that in all such cases the bond stresses do not exceed those specified under Regulation 80.

The maximum permissible stress might reasonably be increased to 20,000 lb. per sq. in.

Regulation 111 allows steel wire, expanded metal, or other reticulated steel to be used for slabs, small beams, minor details, or for reinforcing against shrinkage and temperature stresses, with unit stresses determined after testing the various materials.

Regulation 112 provides that the reinforcement must be free from flaking, rust, scale, or coatings of any character, which tend to reduce or destroy the bond.

Regulation 113 states that 1 : 2 : 4 concrete shall generally be used, but for columns a richer mixture is preferable.

Regulation 114 provides that the City Building Surveyor shall have the right to select samples of the steel or concrete for testing at any time during the progress of the work.

Regulations 121 to 132 inclusive deal with the mixing of the concrete and the placing of the concrete and reinforcements.

The concrete is to be mixed in exact proportions, and until it is homogeneous and of uniform colour.

Generally an approved mixing machine is to be employed, and when hand-mixing is adopted the ingredients are to be turned at least six times, or until the mass is homogeneous in appearance and colour, on a water-tight platform.

The consistency is to be such that the concrete will flow sluggishly into the forms and surround the reinforcements, and to be in such a condition that the concrete can be conveyed from the mixer to the forms without any separation of the coarse aggregates from the mortar.

No remixing of concrete which has partially set is permitted.

The concrete is to be conveyed to the forms as rapidly as possible, and to be thoroughly compacted, care being taken to prevent the formation of laitance, and laitence, if formed, is to be removed.

The reinforcement must be placed in its proper position, and held in place until the concrete has been deposited.

When the deposit of concrete is suspended all necessary grooves are to be made before the concrete has set, and when the work is resumed the surface of the old concrete is to be roughened, cleansed, thoroughly wetted, and then slushed with a mixture of one part of cement to one part of sand.

All concrete exposed to premature drying must be covered with sacking and kept wet for a period of at least seven days. Where concrete is conveyed by a chute it must flow in a continuous stream, and the chute must have an angle of about one vertical to two horizontal.

The work is to be so organised that the beams and slab are poured in one operation, and the concreting of any member must be carried out as continuously as possible.

The forms are to be cleaned and thoroughly wetted before concreting is commenced.

When a cessation of work is unavoidable the break is to be made with a vertical plane at the centre of the span of beams or floors.

No joint is to be made close to a concentrated load.

When tensile reinforcements are spliced the length of lap is to be determined on the basis of the safe bond stress, the stress in the bar and the shearing resistance of the concrete at the splice.

No splices are allowed at points of maximum tension. In columns, bars, more than $\frac{3}{4}$ in. diameter, not subject to tension, are to have their ends squared and butted together in suitable sleeves; smaller bars are to be lapped, as required for tensile reinforcements. In concrete foundations suitable bearing plates must be provided for supporting the bars or the bars must be carried into the footing and designed to transmit the stress in the steel to the concrete by means of the bearing and bond resistance.

Regulations 174 to 177 inclusive deal with piles.

The safe sustaining power is to be calculated by the formula:

$$P = \frac{2WH}{S+1}$$

when an ordinary drop hammer is used, and by the formula

$$P=\frac{2WH}{S+0{\cdot}1}$$

when the piles are driven by a quick-action steam, pneumatic, or similar drop hammer or ram.

P = safe bearing pressure per pile in tons.
W = weight of ram in tons.
H = height of fall of ram in feet.
S = penetration in inches of pile under the last blow.

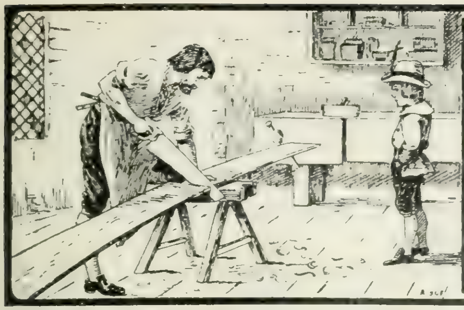
If concrete piles are cast in position without driving the safe bearing capacity is to be calculated by the preceding formula of the force used in driving the casting mould or by such test as the City Building Surveyor may decide, provided that the factor of safety is not less than that for driven piles.

The words "of the force used in" must mean "according to the data obtained when."

Regulation 181 states that columns carrying wind stresses must be firmly anchored into solid rock or to a mass of concrete whose weight is at least one and a half times the uplift.

Regulations 182 and 183 deal with foundations under columns, and provide that, if they are not symmetrical, the centre line of the column must be within the middle third of the foundation, and that the average intensity of pressure on the formation must not exceed one-third of the safe loads allowed for the bearing capacity of the soil.

If the centre line of the column is not within the middle third of the foundation the column must rest on a reinforced concrete cantilever or raft foundation, having a column or columns at the inner end, the foundation being designed for the combined loads.



REINFORCED CONCRETE SILOS.

By the courtesy of the Food Production Department, we are able to reproduce the text of the pamphlet which the department has issued on the subject of silos together with the illustrations given on p. 348 of this article. We have added some comments of our own as an introduction to the pamphlet, which appears on p. 346.—ED.

It is very important that no possible method of increasing the food supply for cattle should be neglected at the present time, and it is satisfactory to know that the authorities have taken up the matter and evolved a scheme which will undoubtedly commend itself to all agriculturists.

This scheme deals with the erection of silos, and drawings and specifications have been drawn up for the use of farmers and landowners which will enable them to get the work executed in accordance with good practice. It has been recognised for some time that the preserving of green fodder for winter feeding could advantageously be extended to all farms having a herd of about twelve or more cows, and some of the more progressive farmers have erected silos of various kinds, but they have not always been properly advised, and the results have, therefore, not been quite so satisfactory as they should have been. Of the various materials which have been used in the construction of silos experience shows that reinforced concrete is by far the best, and this is not surprising when it is realised that the structure to be ideal should possess the qualifications of being water and air tight, waterproof, ratproof, fire-resisting, and permanent.

It will be clear that timber, even if available, is not a satisfactory material, and yet it has been adopted by inexperienced persons in the past with often disastrous results.

A large number of silos have been, and will be, erected by the landowner with his own labour, and hence it is absolutely essential that any official instructions and information which are issued shall be perfectly clear and simple. The pamphlet and drawings which are reproduced with these notes are intended to assist the landowner in his dealings with a contractor rather than in the event of his executing the work himself, and thus the needs of the case are only partially met.

It is certainly advisable to encourage the erection of the silos by competent contractors, and, further, the Department dealing with Food Production are prepared to give expert advice in all cases where construction of a silo is contemplated, and forms and centering will be lent at a moderate charge, so that every inducement is put forward to make farmers proceed with a silage scheme.

With reference to the type of silo which has been adopted as a standard the proportion of height to diameter is 2 to 1, and this is the least that should be employed. It is generally preferable to make the height two and a half times the diameter, and such a proportion will prove economical in construction, and in feeding the cattle it is essential that a *complete* layer of silage be removed every day, this being, say, about 2 in. thick, and where a large diameter is employed this is not always possible. The increase in pressure due to the increase in height is not very large, as the side pressure from the silage is only about 11 lb. per sq. ft. for every foot of depth, and the resistance of the main or horizontal rods is obviously increased as the diameter is reduced.

In many silos the floor level is kept down below the ground level for a distance which should not exceed 4 ft., and this has some advantages from a constructional point of view. In the case of a clay soil the foundations should be taken down below the level of atmospheric influence, and where the floor is kept at ground level this represents so much expense without any increase in the capacity, and thus it is disadvantageous. With a floor level about 4 ft. below the ground level there is additional resistance to wind pressure in exposed situations, and the total height of the lift when filling the silo is also somewhat reduced.

The great advantage, however, of keeping the floor at about the ground level is that drainage from the bottom is facilitated, and it is this factor, no doubt, which influenced the design.

It would be preferable also to have some reinforcement in the concrete forming the floor to prevent cracks occurring in this, and by connecting the floor and wall reinforcement good sound construction is obtained which results in one monolithic structure. This is particularly important where the ground is poor or uneven in resistance.

It is highly important that the walls of the silo are watertight, not only to keep out any water from the outside but also to prevent the silage juices from escaping, and thus it is not advisable to use concrete walls of less thickness than 6 in. In the design here illustrated (see p. 348) a cement rendering ¾ in. thick is included on the inside, but, generally speaking, if the concrete is good it will be sufficient if the walls are brushed over both inside and out with a wash composed of equal parts of good Portland cement and sand mixed to a creamy consistency.

It is somewhat surprising to find that thatch is suggested as one of the materials that can be used for the roof, considering that fire-resistance and permanence are essential. With the use of thatch the difficulty of keeping this in order will tend to cause neglect, and in time the covering will become defective and the silage will be spoilt. The same remarks apply in a lesser degree to corrugated iron, another material proposed. The most suitable method in the case of a reinforced concrete silo will be that of using a light reinforced concrete roof,which can be easily and economically formed with light bars or barrel at the hips, with expanded metal or similar filling in the panels. This can be attached to the walls and a watertight roof constructed which will require no maintenance.

We now give the circular issued by the Food Production Department,together with the design for the reinforced concrete silo referred to in the circular :

TERMS OF THE DEPARTMENT'S OFFER.

" In view of the shortage of the usual feeding stuffs for cattle, the Food Production Department is satisfied that it is both commercially to the interest of farmers and nationally important that the use of silage, on up-to-date lines, should be greatly extended. The Department is, therefore, prepared to help agriculturists who wish to build silos on their farms in the following ways :

(*a*) By giving expert advice in all cases where the construction of a silo is contemplated.

(*b*) By supplying free of charge full working drawings, specifications, and bills of quantities for two sizes of silos constructed in either reinforced concrete or reinforced brickwork, in cases where the landowner or farmer wishes to make his own arrangements for building the silo. (The drawings, etc., can be seen at the office of the County Agricultural Executive Committee, and obtained from the Food Production Department.)

(*c*) By lending at a moderate charge all forms and centering (moulds) needed for the construction of one of the above standard silos, and facilitating the issue of permits for materials.

(*d*) By contracting with the landowner or farmer for the complete construction of silos at a fixed price, which will be quoted after investigation of local conditions.

(*e*) By assisting anyone who wishes to construct a concrete or brick silo of some approved type, but of a size or design other than one of the standard types mentioned above, to obtain priority certificates for the materials needed. (Special designs cannot be provided by the Department in such cases.)

It is to be clearly understood that while the Department is prepared to do all that it can to help farmers in this matter, nothing stated herein or upon the drawings or other particulars supplied by the Department shall be construed to imply a guarantee of any of the matters or things referred to.

THE SILO.

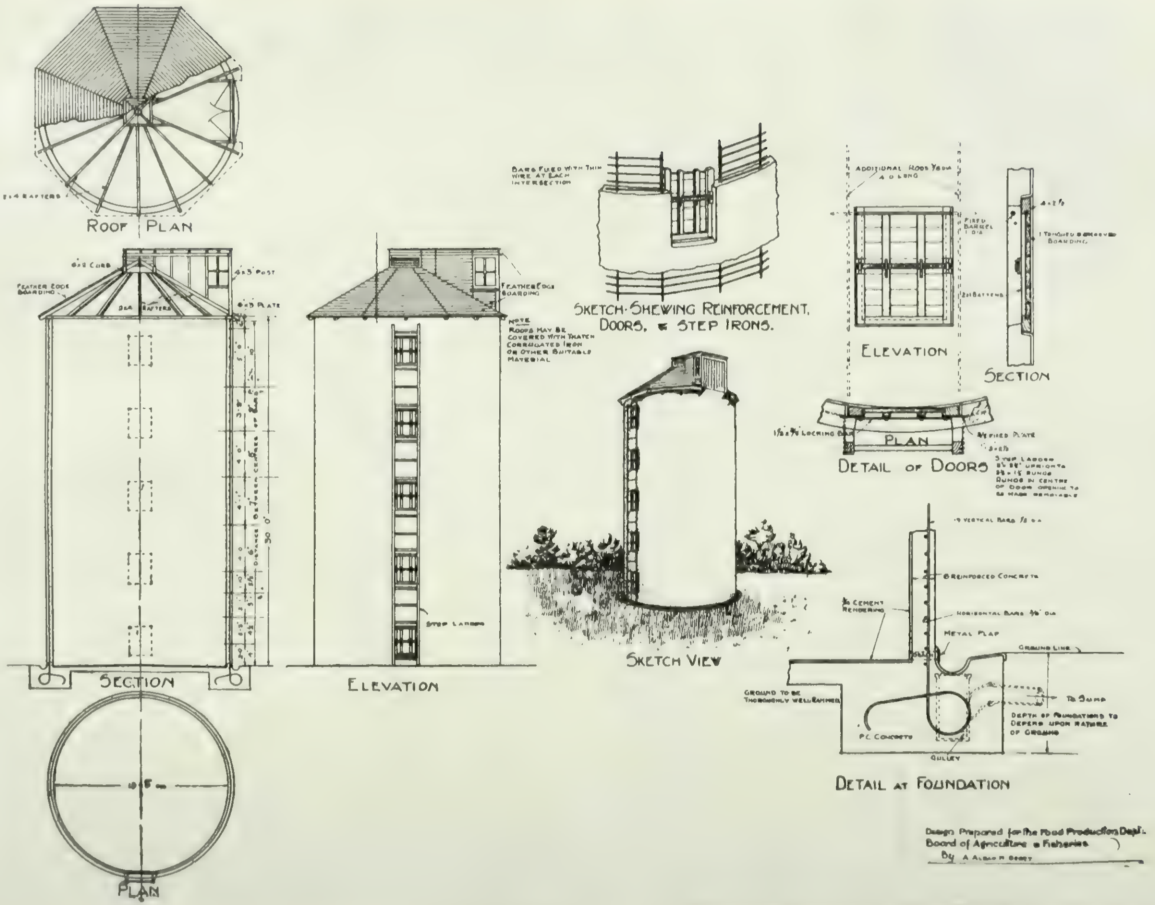
Two sizes of silo have been provided for :

Size 100.—15 ft. diameter by 30 ft. high ; capacity 5,300 cu. ft., or nearly 200 cu. yd. ; holding, say, about 100 tons of silage. Suitable for a herd of about twenty-five cows.

Size 50.—12 ft. diameter by 24 ft. high ; capacity, 2,710 cu. ft., or about 100 cu. yd. ; holding, say, about 50 tons of silage. Suitable for a herd of about twelve cows.

Each size can be constructed either in reinforced brickwork, style " B," or in reinforced concrete, style " C." Thus, for reference purposes a silo built in brick 15 ft. diameter by 30 ft. high would be described as a " 100 B " silo, and one of 12 ft. diameter by 24 ft. high made of concrete would be styled a " 50 C " silo.

Each silo takes the form of a hollow round tower covered with a wooden roof in which ventilation is provided. It is fitted with a large door at the top through which it is filled. There are also a number of smaller doors arranged one above the other up the side of the silo which are used in succession as the level of the contained silage sinks, for its delivery when required for feeding. Provision is made for suitable drainage and for steps by which the doors can be reached from the ground. These silos are intended to be filled with unchaffed


ROOF PLAN
3×4 RAFTERS
6×3 CURB
FEATHER EDGE BOARDING
4×3 POST
6×3 PLATE
3×4 RAFTERS
30′ 0″
DISTANCE BETWEEN CENTRES OF BARS
SECTION
PLAN
10′ 6″
ELEVATION
STEP LADDER
FEATHER EDGE BOARDING
NOTE
ROOFS MAY BE COVERED WITH THATCH CORRUGATED IRON OR OTHER SUITABLE MATERIAL
BARS FIXED WITH THIN WIRE AT EACH INTERSECTION
SKETCH·SHEWING REINFORCEMENT, DOORS, & STEP IRONS.
SKETCH VIEW
ADDITIONAL RODS ⅜″ DIA 4′ 0″ LONG
FIXED BARREL 1″ DIA
2×1 BATTENS
ELEVATION
1″ TONGUED & GROOVED BOARDING
SECTION
1½×⅜ LOCKING BAR
PLAN
FIXED PLATE
DETAIL OF DOORS
STEP LADDER
RUNGS IN CENTRE OF DOOR OPENING TO BE MADE REMOVABLE
VERTICAL BARS ½″ DIA
6″ REINFORCED CONCRETE
½″ CEMENT RENDERING
HORIZONTAL BARS ⅜″ DIA
METAL FLAP
GROUND LINE
GROUND TO BE THOROUGHLY WELL RAMMED
TO SUMP
DEPTH OF FOUNDATIONS TO DEPEND UPON NATURE OF GROUND
P.C. CONCRETE
GULLEY
DETAIL AT FOUNDATION
Design Prepared for the Food Production Dept.
Board of Agriculture & Fisheries
By A. Albert Berry

[*Reproduced by courtesy of the Food Production Dept.*

Details of Construction.

A REINFORCED CONCRETE SILO.

crops by means of the ordinary elevator with horse gear such as is to be found on many farms. There is nothing, however, in their construction to prevent farmers from adopting the American system of chaffing the crop and blowing it into the silo if they prefer this method of filling, and have, or can obtain, the necessary plant consisting of engine, chaff cutter and blower. The Department cannot, however, undertake to obtain the necessary permits for either the manufacture in this country, or shipment from abroad, of chaff cutters and blowers for this purpose.

COST OF THE SILO.

In order to obtain an approximate idea of the cost of a particular silo it may be assumed that in situations where there are no special local difficulties and where good clean sand and ballast are readily obtainable, a concrete silo of Size 100 C will cost at the present time roughly £310, and one of Size 50C roughly £210.

Where bricks are more easily obtained than ballast, " B Type " silos will probably be preferred, costing roughly £340 for Size 100B, and £235 for Size 50B. In each case it is assumed that the purchaser will himself cart the materials to the site. The estimated weights for each type are as follows : 100 B, 140 tons ; 100C, 102 tons ; 50B, 95 tons ; 50C, 70 tons.

SITE FOR THE SILO.

To save labour the silos should be built close to the cattle sheds, and, if possible, should deliver straight into them. It is very necessary that there should be a good road and ample space around the base of the silo on the side from which filling operations are to take place.

CROPS FOR THE SILO.

The Technical Division of the Department is prepared to give information as to the choice of suitable silage crops and as to the process generally. The following is a list of crops which could be well and efficiently preserved for cattle fodder if a silo were erected in time for their reception this year, or may be grown for silage in 1919.

APPROXIMATE ACREAGE REQUIRED TO FILL STANDARD SILOS.

Crops for Silage.	Silo " Size 100 " Acres.	Silo " Size 50 " Acres.
Maize	6	3
Oats and Vetches	9½	4¾
Lucerne (two cuts)	9½	4¾
Red Clover and Ryegrass	13	6½
Red Clover	15	7½
Meadow Grass	17	8½
Sainfoin	12	6

ADVANTAGES OF SILAGE.

1. It is a means of preserving green fodder in a succulent state for winter feeding.

2. It is independent of weather, and is, therefore, safer than haymaking in wet seasons.

3. On heavy clay lands or on light soils in dry districts, where roots are precarious, there is almost a certainty of obtaining a silage crop.

4. It is cheaper than root growing under unfavourable conditions.

5. If the silage crop is sown in early spring, or, preferably in autumn, it can be got off in time for turnips or rape to be taken, or a bastard fallow made.

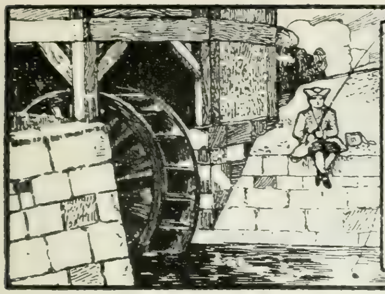
6. The usual silage mixture of oats and vetches is a useful cleaning crop. Stubble land, therefore, which in the ordinary course would be bare-fallowed. may safely be sown with oats and vetches and cleaning completed in time for autumn corn by means of a bastard fallow.

7. Stock fed on silage made from leguminous crops—*i.e.*, clover, lucerne, sainfoin, and vetches—will require less oilcake than stock fed on roots; moreover, such crops tend to increase the fertility of the land.

8. It will enable poor heavy land now in grass to be brought under tillage, cleaned and improved.

9. The labour involved in feeding silage is very much less than that of feeding roots.

10. It will be seen by a reference to Leaflet No. 9 (to be obtained from the Board of Agriculture and Fisheries, 3, St. James's Square, S.W.), which deals with ensilage, that in cases where a farmer finds himself short of the usual silage crops the silo may be filled up with coarse grass, hop bines (directly the hops are picked), and even nettles and weeds. Materials which otherwise stock would reject may be made into edible silage."



CONCRETE RESERVOIRS AS SUBSTITUTES FOR STEEL OIL STORAGE TANKS.

By the courtesy of the Concrete Oil Storage Co., of Tulsa, Oklahoma, we are able to publish the following interesting photographs of a large concrete reservoir of oil storage in America. Our particulars are taken from the "Oil Trade Journal."—ED.

THE suitability of concrete for oil reservoirs is a question that has been much discussed, and reservoirs and tanks for oil storage have from time to time been built with satisfactory results in the United States and, we believe, on the Continent.

The ever-increasing price of steel plate, however, has caused those concerned in the storage of oil in the United States to give special attention to the use of reinforced concrete reservoirs for oil storage on a large scale. According to the journal from which we quote the following particulars, steel tankage in August, 1917, was costing more than 60 c. per barrel, whilst the large 55,000 bbl. tanks were, approximately, worth $35,000.

The Trapshooters-Eureka lease in Towanda township, Kansas, now has 100,000 bbls. of concrete storage in course of construction, and other concerns have been getting estimates.

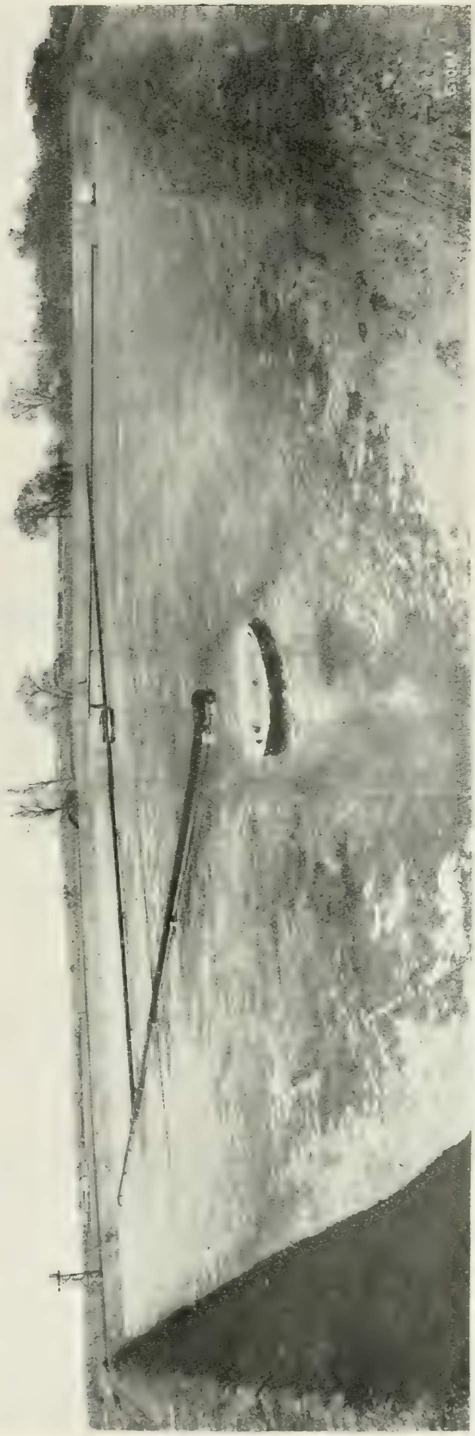
The Concrete Oil Storage Co. of Tulsa has just completed for Messrs. Cosden & Co. a 165,000-bbl. reinforced concrete tank at the Cosden refinery. M. J. Munn, head of the Gypsy Oil Company's geological department, is the inventor of this type of underground concrete tank. The entire reservoir, including roof, is of reinforced concrete construction. The company claims that under its patented system it is impossible for seepage to occur. The tank being underground, the roof will be covered by a body of water which will be retained there by an earthen embankment all around the top. Nothing will be visible above ground except a pond of water. Excavation has been made at the Cosden plant for a 500,000-bbl. tank of the same design.

In regard to the advantages of this type of storage tank, one of the company's officials says :

" Gas vents are arranged by means of insulated pipes, which come up from the tank through the water ; these pipes then bend back into the water. Waterlet valves are arranged in the pipes to control the escaping gas. The gas escapes into the water, and then bubbles off. Manholes are arranged in the roof for entering the tank. These are entirely submerged when not in use.

View showing Inside Section of Contact between Sloping Side Wall and Floor. Attention is called to the fine close finish of the Concrete.

" The patents cover all forms of submerged or underground concrete oil storage. Utilisation of natural resources is also covered by the system —viz., use is made of valleys or small streams by placing these concrete



View of Top of 165,000 barrel Concrete Oil Storage Tank before water was placed on same. The Illustration shows Venting System and also Manholes entering the Tank.

oil reservoirs across the stream in such a way as to utilise the rain water caught by an upper dam to submerge the tank.

" The body of water covering this tank is an insulation against fire and lightning, and being an absolute protection the insurance question is entirely eliminated, and on this basis alone the tank pays for itself within five or six years. This body of water, together with the fact that the tank is underground, makes a cool receptacle for the oil and reduces to a minimum the losses through evaporation. The resistance of the waterlet valve to the escaping gas also retards evaporation.

" These tanks require no upkeep cost, will not deteriorate with age, and do not require painting. Economy in space is also a factor worth considering."

A number of large concrete oil storage tanks are in use in California and Mexico.

CONCRETE SIMPLIFIED.

By THOMAS POTTER.

A Practical Guide to the General Use of Concrete.

(Concluded).

XII.

CONCRETE ON THE FARM.

WALLS AND FOUNDATIONS.

MONOLITHIC concrete is best adapted for walls of farm buildings owing to the lay-out being usually free from any irregularities, while comparatively few doors and windows are required, and strength is the main object. Blocks and slabs do not afford the same resistance to rough usage.

For one-storey buildings and farmyard and enclosure walls 7 in. in thickness is ample, and 9 in. for two stories, and for partitions or divisions 6 in., the proportion of matrice and aggregate being 1—8. Raft foundations, where the nature of the ground is suitable, are most economical, owing to the considerable area which farm buildings usually cover, and they serve for floors or as a base for the paving. All walls should be reinforced with two rows of $\frac{1}{4}$-in. rods 1 in. from either face and each 18 in. in height, to resist temperature changes.

Oak guard posts should be fixed against the corners of all concrete buildings, and where rainwater pipes are required it is an advantage to leave recesses in the walls by means of a wood core inserted in the concrete, and afterwards withdrawn, of sufficient size to permit the pipes to be fixed therein for protection against cart wheels and other possible sources of damage.

PAVING AND FLOORS.

Pavings and floors may be of various kinds, but each should have a bottoming of rough core 5 or 6 in. in thickness. If the soil is loose it should be removed, coarser rough material taking its place and both being rammed or rolled.

ROOT-HOUSES AND CATTLE FOOD STORES.

For buildings not subject to very much wear and not used for cattle, such as root-houses, stores for cattle food, etc., cement concrete, 1—6, and 4 to 5 in. in thickness, should be employed, the aggregate being boiler ashes, brick *débris*, slag, or some similar material, the largest $\frac{3}{4}$-in. mesh down to coarse sand size and well tamped or gently beaten with a beater, as described in Chapter IX. The following day it should be grouted with cement and coarse brick, ashes, or slag sand, half of each, and well worked in with a bass broom. Floors of this description become very hard and withstand long wear.

COW-HOUSE AND PIGGERY FLOORS.

For cow-houses, piggeries, and similar places the concrete should be 1—6 or 7, 3 or 4 in. in thickness, and faced with cement and a similar kind of sand to that described for root-house floors, 1—3, $\frac{3}{4}$ in. or 1 in. in thickness, and finished with a wood hand float, not a steel trowel. If considered necessary to prevent any possible slipperiness, a revolving brass tool, made for the purpose can be purchased which has numerous projecting nibs on its surface, and when the cement mortar has nearly attained hardness it is rolled therewith, and this produces indents insufficient in depth to get clogged with dung, but which get cleaned out each time a floor washing takes place.

PATHS AND FOOTWAYS.

Garden, cottage, and farmyard paths and village footways can be economically formed in a similar manner, and, although they wear in course of time and the indentations begin to disappear, slipperiness does not result unless the surface is coated with slime and filth. Where paths and footways are of considerable length they should have at every 10 or 12 ft. strips of wood $\frac{1}{4}$ in. in thickness or less and the depth of the concrete in width, or pieces of hard felt inserted to break the concrete up into sections to prevent cracks from temperature changes, which then only occur, if any, where the sections join. These temperature strips can be left to take care of themselves, and when they decay the concrete is unaffected thereby and the joints then resemble those seen between ordinary stone paving. If a kerb is required it can be formed *in situ* or cast in the same way as lintels, to any required length.

River and pit gravel, beach or shingle should not be used for floors, footways, or paving unless faced as described, as, although the aggregate will not wear by attrition, the cement does to some extent in course of time, and a rough pimply surface is the result, the interstices becoming filled with dirt.

STABLE PAVING.

Stables require a different description of paving from other stock buildings, owing to the pounding effects of horses' iron shoes. The finish on the concrete is usually cement and granite chips or sand, 1—3, and about 2 in. in thickness, but frequently less. To prevent slipperiness it must be channelled of a V-shape, similar to blue brick stable paviors. This is performed by lining out the surface before the cement has set, in small squares, a workman then hammers a piece of hard wood about 4 ft. in length, having a bevelled edge corresponding with the V joint, in the cement mortar until the correct shape is attained. This is a primitive arrangement, and another plan is to cut out the cement to form the channels. The former has the advantage that, owing to repeated hammering, the cement acquires density and hardness where most required. This description of paving is obviously expensive, but at normal prices for cement no more, sometimes less, than blue Staffordshire stable paving. It has an advantage in possessing no joints for urine to get through, and is used mostly for carriage horse, hunter, and cavalry stables.

COPING.

Fig. 10 shows a simple kind of coping formed *in situ* adapted for farmyard division, enclosure, garden and other walls. Half-circle thin wood templates are fixed on the walls 9 or 10 ft. apart, two workmen with a long wood rule or straight edge apply fine concrete between the templates, and after removing the latter finish it with cement and sand, 1—4, with a steel plastering trowel. It is proof against all kinds of weather and injury from cattle or passing vehicles.

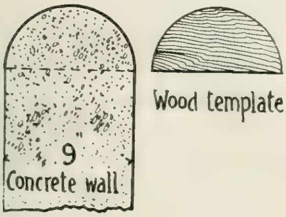


Fig. 10.

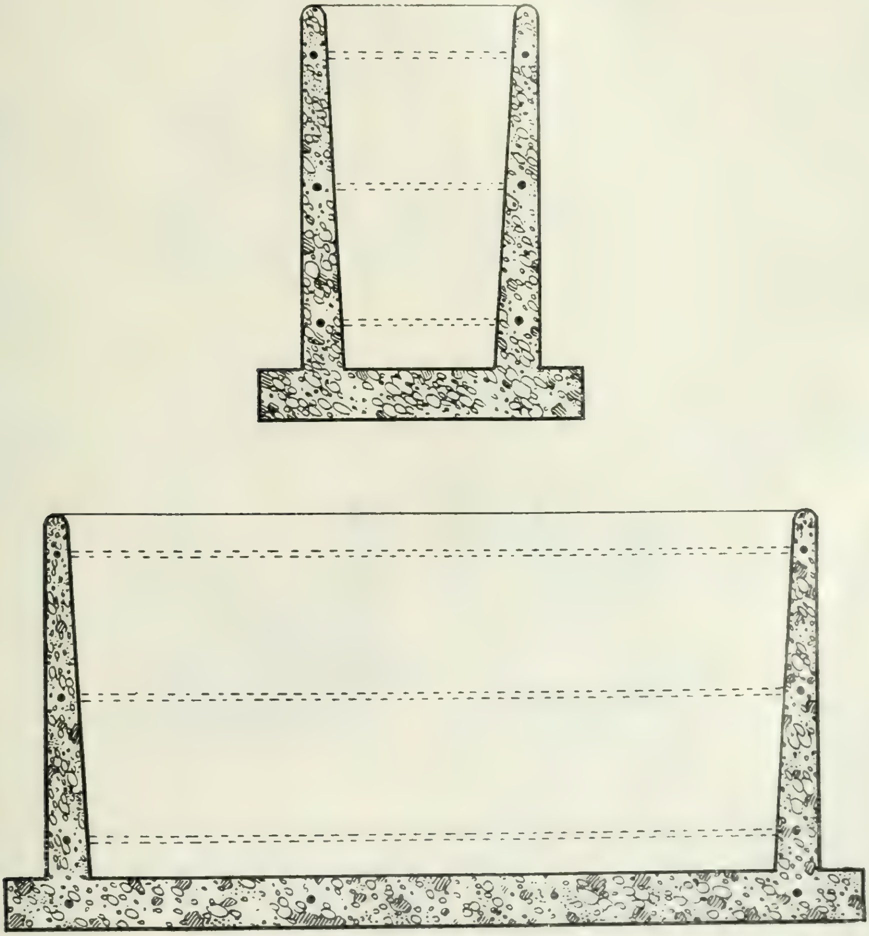


Fig. 11

HORSE TROUGHS.

Fig. 11 is a plan and section of a cattle drinking trough, which can be of any size required and either built *in situ* or made portable. If the latter, weight has to be considered. The form arrangement should consist of ledged boards for the sides and ends to be easily removed, similar to *Fig.* 6, Chapter X., and a cradle internal form of a suitable size and shape to allow for the concrete. The cradle should have top and bottom rails about 3 in. deep and 2 in. thick to sides and ends, and ¾-in. narrow boards nailed vertically thereto, and no bottom. When the concrete bottom has been levelled the outside forms are fixed and the cradle placed in position and stayed. The reinforcing rods going through sides and ends should be hooked or welded together at the angles and embedded in the concrete as the latter is being deposited in place, and which should be gently tamped or punned with a piece of wood. The cradle should be soaked in water or covered with wet sawdust for twenty-four hours before use that it may not swell when in place, then dried and a thin coat of Leeds grease or soft soap applied to keep the cement from adhering thereto. In two days the cradle can be withdrawn, the outside forms released and the outside and inside of the trough plastered smooth ½ in. thick with cement and granite sand 1—2. The concrete should be 1—5, the sides and ends 3½ in. thick at the bottom and 2½ in. at top, and the top edges rounded by hand. For smaller portable troughs a modification of the forms, cradle, etc., can be adopted. Boiler ashes make a suitable aggregate, being lighter than some others. The angles should be rounded to prevent injury to cattle. Food mixing troughs for live stock, and bins for dry cattle food, etc., can be made in a similar way to water troughs, and, unlike wood, are imperishable and vermin proof.

CATTLE MANGERS AND PIG TROUGHS.

Fig. 12 shows concrete bullock and cow mangers formed *in situ* by means of a ledged wood front 8 to 10 ft. in length, rigidly stayed, and a wood form or mould for the inside fixed at the right height in any convenient way, the concrete being then filled in between the outer and inner forms and well tamped. When a length is finished and the concrete is sufficiently hard, the forms are moved on and refixed for another length. The concrete should be 1—6 the aggregate graded from ¾-in. mesh to coarse sand size, the rounded

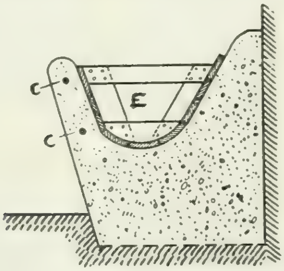


Fig. 12.

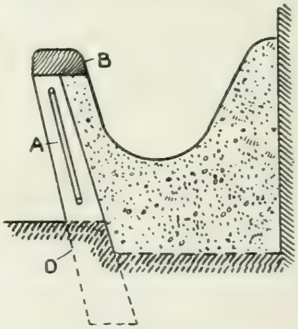


Fig. 13.

top edge done with a steel trowel, using a fine aggregate, the thickness of the front on the top edge 2 to $2\frac{1}{2}$ in. The inside and outside surfaces should be finished with cement, and ashes or similar sand, 1—3, trowelled smooth with a plasterer's trowel. *CC* are $\frac{3}{8}$-in. reinforcing rods and *E* the inner form.

Where cattle ties are necessary these can be formed by means of posts about 4 × 3 in. with their arrises rounded, fixed in the ground and sliding irons with ring attached driven therein as *Fig.* 13. *A* is a sliding iron, *B* wood cap fixed to the posts, *D* wood post, *E* form mould. Pig troughs can be made in a similar way or cast in one piece to be movable.

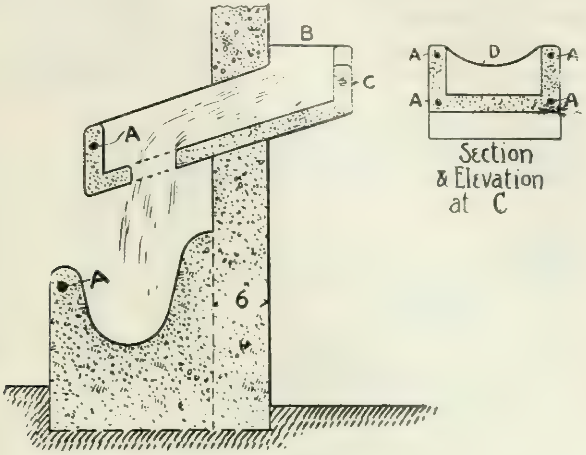


Fig. 14.

PIG FOOD SHOOTS.

Piggery walls are usually about 4 ft. in height, and the method of feeding pigs is either by lifting the food over the walls in buckets or passing it through wood shoots in the walls, either method resulting in waste. *Fig.* 14 shows a concrete shoot made in one piece, which prevents waste. *AAC* are $\frac{1}{4}$-in. reinforcing rods; *B* the top of the shoot; *D* curved end for the bucket to rest on. The mould can be readily made by any intelligent carpenter, and there is no difficulty in applying the concrete.

RAINWATER TANKS.

Underground tanks for rainwater from roofs may be either round, square, or oblong. For the former a drum divided into three sections is necessary, but an oblong is the best, for various reasons, and the simplest to construct. The posts should be about 7 in. by $2\frac{1}{2}$ in., fixed 4 or 5 ft. apart, and well stayed top and bottom. A few boards should be cut in between the posts and fixed thereto to carry up all the walls at the same time, lifting them higher as the work proceeds until the top is reached, when the woodwork can be released. The concrete bottom should be done first and the walls built thereon. It is advisable to divide the tank by a cross wall into two equal portions to enable one to be in use while the other is being cleaned out from leaves, bird droppings, etc., that find their way through the drains.

The top or cover may be formed with rough home grown $1\frac{1}{2}$-in. boards bearing about $1\frac{1}{2}$ in. on the walls, and upon these 5 in. of concrete, 1—6, 1 in. mesh to coarse sand size, reinforced with $\frac{1}{4}$-in. rods 9 in. apart, embedded 1 in. from the under side, and with similar rods crossing them at right angles, the top being then grouted with cement and sand, 1—3, and 6 in. of earth spread over or turfed to prevent the effects of temperature changes.

The inside of the walls should be cemented with cement mortar, 1—3, $\frac{3}{4}$ in. to 1 in. in thickness, trowelled smooth, and the last operation 2 or 3 in. of concrete added to the bottom concrete and cemented, the latter having probably got damaged somewhat through working thereon in building the walls.

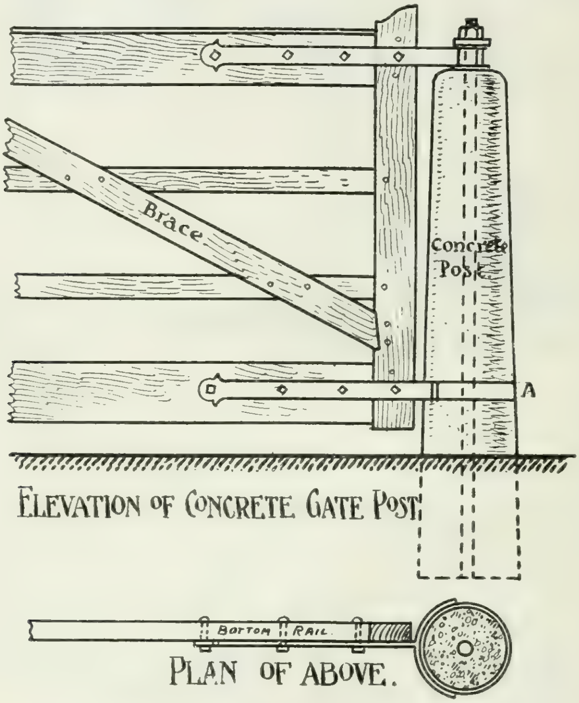


FIG. 15.

The concrete walls, 1—6, scarcely ever require to be more than 6 in. in thickness unless the ground is of a loose or expansive character.

The loss of the cover boards is more than compensated for by the saving in labour and materials in forming a platform with supporting posts internally, but it is a question of comparative cost.

An iron manhole and cover should be let in the top for access, and a 3-in. or 4-in. cast-iron pipe, 6 ft. in length, with a fine galvanised iron wire top for ventilation.

FENCE POSTS AND GATE POSTS.

Fence posts may be made in wood moulds and of any desired size and length. A usual size is 5 in. by 4 in. at bottom and 3½ in. by 4 in. at top, and the aggregate crushed brickyard *débris*, boiler ashes, or any of the aggregates described in Chapter I., except clinker and chalk. If intended for fixing wire thereto and the aggregate is either of the two first named, it can be attached by means of wire staples, or if the concrete is too hard holes can be drilled therein a part of the way with a brace and a Morse drill. If splayed tops are required an angular loose piece of wood should be put in the moulds to form a core.

The posts can be cast on any level platform, but one of concrete faced with cement is best. If pallets or bottoms are used the posts can be removed much earlier. The mould and platform or pallets should have a brush over with Leeds grease each time they are used, and when removed the posts stacked with an air space between in the open air or under cover, but protected from the sun's rays. When taken out of the moulds they should be washed with neat cement of the consistency of cream, after being well saturated with water. The reinforcement should consist of four ¼-in. rods, one at each angle and 1 in. therefrom. If rods or tubes are used they should rest on slots sunk in the face of the posts by means of prints of wood fixed in the moulds at the time of casting, a simple arrangement. The rods are attached to the posts by encircling wire ties. To cast holes in the posts for rods to pass through is a troublesome process, and the fixing as well. The proportion of materials should be 1—5 and the aggregate graded from ¾-in. to coarse sand size.

Gate posts are made in a similar way, but usually in a single mould on account of their size and the hooks having to be embedded in the concrete. Ordinary field gate posts should be about equal in size to or somewhat less than is usual if oak is employed.

Gates are occasionally required to open either way or back to the line of wall or fence, to allow a clear opening for loaded wagons or for live stock, which often gather together in a field waiting to pass through. If the gate opens only on the field side some congestion ensues. *Fig.* 15 shows a gate post which allows the gate to swing either way and back to the line of fence. The bottom hinge revolves round a circular iron ring, *A*, made of 2¼-in. by 1¼-in. bar iron, and the top hinge round a ¾-in. iron rod embedded in the centre of the post.

The form is of wood in two halves, held together temporarily by wire bonds or other convenient method. The concrete, 1—5, the aggregate ¾ in. to coarse sand size, is poured in the top of the mould *in situ* after the latter has been stayed in position. The mould can be liberated in two days and is available for any number of posts.

STALL DIVISIONS.

Concrete stall divisions for cow-houses, stables, and similar buildings are a great improvement on wood and iron. They should be cast in one piece and from 2 to 3 in. in thickness, according to the purpose they are required for. Granite chips make the best aggregate on account of the rough usage they are subject to, 1—5, and should be faced quite smooth with cement and granite sand, 1—1 or 1—2.

No heel posts or top rails are necessary, but the ends and tops should be rounded, and finished the same as the sides; $\frac{5}{8}$-in. iron rods should be inserted in the centre of the concrete 6 in. apart in height, and a few small vertical rods are a useful addition. They should rest on concrete about 6 in. beneath the paving and concreted on either side 6 to 9 in. in width.

The advantage of this kind of division is that there is nothing to rust or rot, no lodgment for dust and dirt, and they can be readily kept clean. They can be purchased of manufacturers ready for fixing.

PONDS.

Ponds for catching rainwater and dew ponds are common on the Sussex and Wiltshire downs, where water is often difficult to procure, and these are often made with puddled clay, which is subject to damage by live stock treading it in holes and causing leakage. If the clay is re-puddled and when dry a layer of cement concrete, 1—6, 3 in. in thickness, placed thereon, the cattle can do no damage. A layer of strong wire netting embedded in the concrete 1 in. from the top will often prevent temperature cracks, but even if this is not employed the clay puddle, being protected, should be watertight.

There are many other features connected with a farmstead which are not difficult to execute in concrete, such as foot and cattle bridges over narrow water-courses in low-lying districts, sluices and hatches in water meadows, cesspools, open channel gutters for water or sewage carriers, liquid manure tanks, cottage pigsties, and repairs to worn cottage stone door sills and steps, all of which can be dealt with by local labour when once a rudimentary knowledge of concrete has been acquired, better than can be described in writing.

RECENT BRITISH PATENTS RELATING TO CONCRETE.

We propose to present at intervals particulars of British Patents issued in connection with concrete and reinforced concrete. The last article appeared in our issue of December, 1917.—ED.

Reinforcement for Concrete Ships.—*No.* 111,384. *Ejnar J. Müller, Voksenkollen, Christiania, Norway. Dated January* 17/17.—According to this invention the steel skeleton of reinforced concrete ships is built up beforehand in the form of finished girders of the truss-type, the several parts of each girder being united together so that a complete self-carrying girder is made up before the concrete is cast.

A series of vertical struts (1) of rolled sections or pipes are built up with top and bottom tie bars (2, 3), diagonal ties (4), provided with turn-buckles (5), being employed to complete the girder.

Fig. 1.

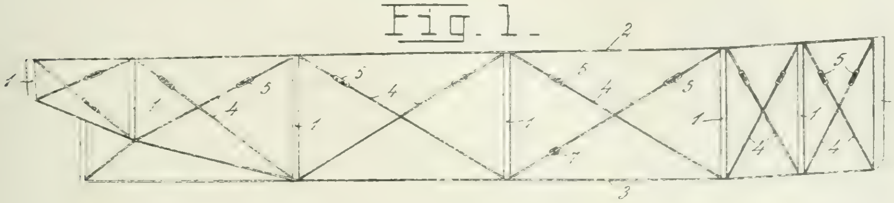


Fig. 3.

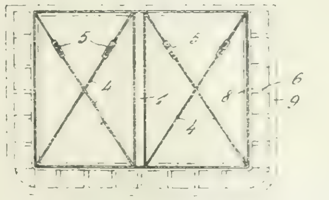
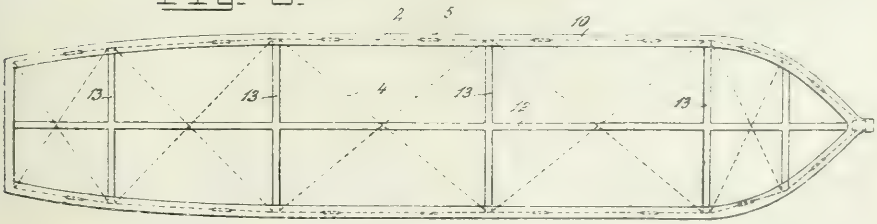


Fig. 2.



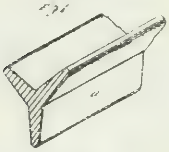
A truss girder system of this type is used between the two outer longitudina walls (10, 11) of the ship, and also within the middle bulkhead (12) if this form of ship s adopted.

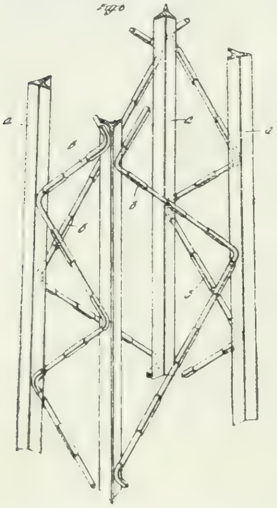
A similar arrangement, *Fig.* 3, is used for transverse bulkheads (13). In this figure a modified construction of ship is shown in which the outer walls and bottom of the ship are hollow, the construction being stiffened by means of metal or concrete stiffening pieces (6).

Wire cables may be employed in place of tie-rods; in this case shoes (7) may be attached at suitable positions to improve adhesion.

Reinforced Concrete Ships. *No.* 112,713. *N. K. Fougner, Toldbodgate 3, Christiania, Norway. Dated May* 1/17.—In order to render reinforced concrete ships better able to resist the action of sea water, the hull is provided with a protecting girdle of about 1 meter depth along the load line.

Immediately after casting the sides of the hull up to the water line the surface of the concrete is roughened and a layer of the protective material is applied. A mixture of Portland cement and sand with iron filings added has proved suitable for the purpose, and the layer may be about one centimetre thick.





Concrete Reinforcement.—*No.* 110,570. *William Marriott, The Grange, Brinton, Melton Constable, Norfolk. Dated October* 20/16.—This invention has reference to concrete reinforcement of the kind in which longitudinal bars are connected together by means of transverse members welded thereto; it consists in forming the longitudinal bars of trifurcated or Y section. The three arms of these bars (*a*) are preferably of equal length, and so designed that there is an angle of approximately ninety degrees between two of them. Where light construction is necessary, these longitudinal bars may be formed by bending sheet metal to the trifurcated form.

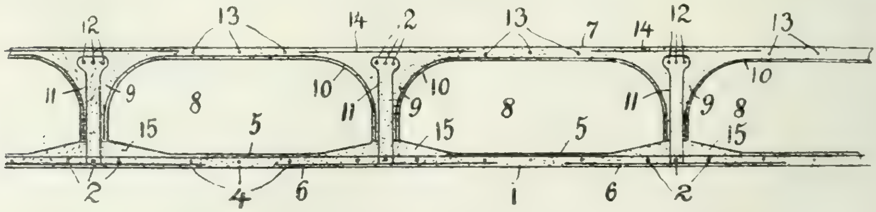
The diagonal bracing members (*b*) are preferably formed, as shown, of alternately square and round sections to improve the key to the concrete.

The invention is specially applicable to reinforcements for concrete construction of plate or slab form, such as name plates for railway stations and tank plates.

Reinforced Concrete Ships.—*No.* 113,873. *N. K. Fougner, Toldbodgate* 3, *Christiania, Norway. Dated May* 1/17.—This invention comprises an improved method of moulding double bottoms of reinforced concrete ships

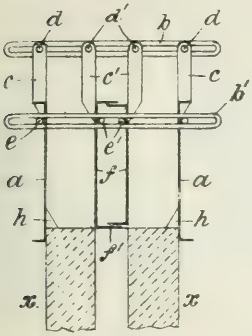
The bottom plate (1) is moulded in the ordinary manner, and is provided with longitudinal reinforcing bars (2 and 4) and transverse bars (5).

The casting of the inner bottom (7) and bulkheads (9) which determine the hollow spaces (8) is effected as follows: Perforated iron sheets or netting (10) are bent



to suitable shape, and are rough cast on the under side with a suitable plaster; these are then placed in position and vertical reinforcements (11) are then placed in position, and horizontal reinforcements (12) are connected to them at the top.

Top transverse and longitudinal reinforcement (13, 14) is then placed in position and the whole inner bottom is then cast, the concrete being thickened at portions (15) abutting the bulkheads.



Moulds for Concrete Buildings.—*No.* 113,664. *George P. Campbell, The Croft, Hightown, Lancs. Dated September* 3/17.—Moulds for concrete buildings constructed in accordance with this invention consist of two side plates (*a*) which are provided with lugs (*c*); these lugs are carried in slots in cross-bars (*b*) by bolts (*d*), and bolts (*e*) carried by the ends of the plates are supported in lower cross-bars (*b*′).

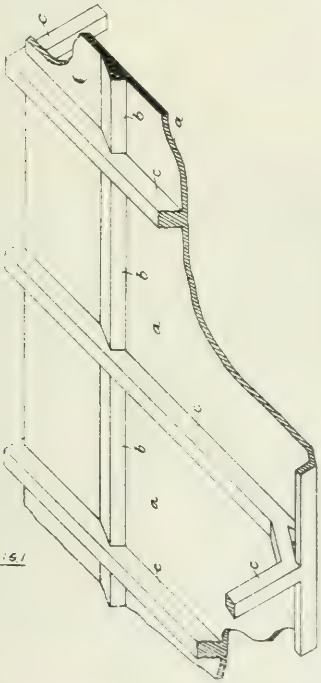
For forming a core, as in cavity walls, plates (*f*) are provided, and are similarly supported from the cross-bars.

When end plates are required they are fitted over the ends of the mould plates (*a*) and are connected to them in any suitable manner.

The mould may be supported in position and rest upon the upper surface of the finished course (*x*) next below by providing feet (*h*) which project inwards; the lower portions of the plates (*a*) project down some distance below the surface of the lower course (*x*).

Concrete Roofs.—*No.* 112,898. *H. Kempton Dyson,* 21 *Great Peter Street, Westminster, London, S.W.*1. *Dated July* 16/17.—This invention, which is particularly applicable to concrete roofs of the saw-tooth type, consists in placing the purlins on the outer surface of the roof; the inner side thus presents a continuous surface unbroken by beams or other protuberances running between the rafters.

The purlin beams (*b*), which act as the secondary beams for the slabs (*a*), are arranged on the outer surface of the latter as shown, and distribute their loads to the rafter beams (*c*), which are also preferably external.



F:G.1

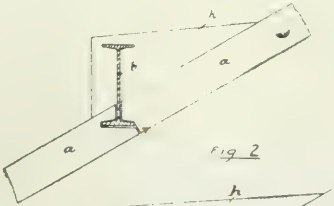


Fig 2

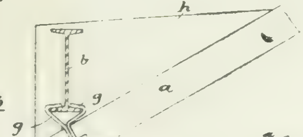


Fig 3

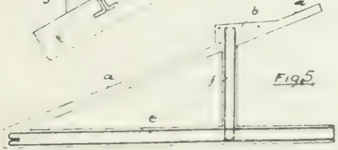


Fig 5.

In the arrangement shown in *Fig.* 2 the purlins (*b*) consist of steel beams, and the pre-cast slabs (*a*) are so shaped at their ends that they are carried by the lower flanges of the beam; whilst in the form shown in *Fig.* 2 hangers (*g*) are supported from the flanges of the beam, and are cast into the slabs which are cast *in situ.*

Fig. 5 shows the invention applied to a reinforced concrete truss in which the purlins distribute their loads through reinforced concrete posts (*f*) to beams (*e*), no rafters being employed.

Fig. 1.

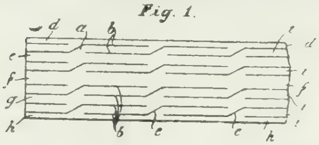


Fig 2

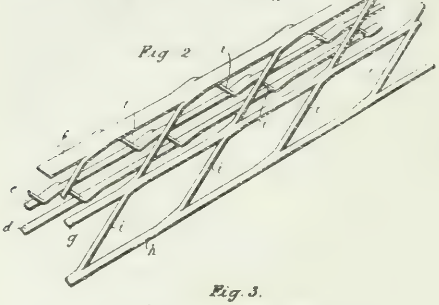


Fig. 3.

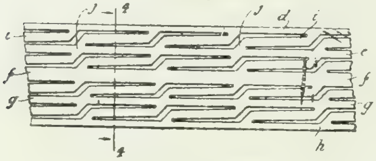
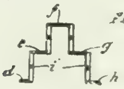


Fig 4

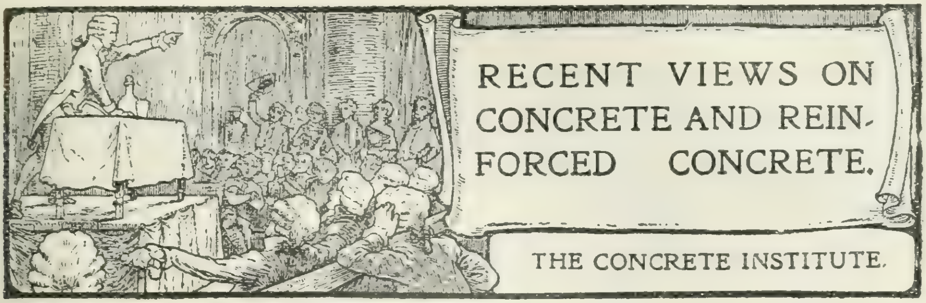


Expanded Reinforcement.—*No.* 114,059. *Arthur Benham, Benhilton, Westbury Road, New Malden, Surrey, and Thomas Freebairn-Smith, 88 Church Road, Hanwell, Middlesex. Dated April 18/17.*—Expanded reinforcement for concrete structures of various kinds is formed in accordance with this invention by cutting a series of eight parallel longitudinal cuts in the sheet material, alternate cuts of one series being connected by inclined cross-cuts to the adjacent set. The slitted sheet is then expanded by pressing the uncut straight portions thus formed into two or more planes.

The strip (*a*) is cut in any suitable manner to provide a number of parallel slits (*b*); each pair of these slits is then connected by a short inclined slit (*c*); the slit sheet is then expanded by pressing to form horizontal portions (*d*), (*e*), (*f*), (*g*), (*h*), connected by diagonal or tie portions (*i*).

MEMORANDUM.

A Shock-Resisting Concrete.—A shock-resisting concrete has been patented by Mr. Lucien Linden. The concrete is composed of (*a*) 100 parts of strong cement, (*b*) 5 parts of moss or turf, well dried and finely cut and pulverised; (*c*) 20 parts of ore rich in iron in fine particles. These substances are formed into a paste by mixing with a binding liquid consisting of five kilograms of quicklime, new from the kiln and broken just before use, and three kilograms of pulverised sulphate of alumina worked up in a cubic metre of clean water. This binding liquid plays an important part in the composition and amalgamation of the paste. An alternative mixture is (*a*) 100 parts of strong concrete, (*b*) 20 parts of soft wood (fine sawdust), (*c*) 10 parts of iron ore, the whole amalgamated with the above binding liquid. The first mixture is said to be suitable for the construction of pipes or ships, and the second can be used without any metallic truss rods, bars, or wires for obtaining a material intended for doors, frames, and roofing. Concrete made with the first mixture will, it is claimed, withstand expansions and contractions with such efficiency that it is almost unnecessary to put hoops round the pipes even when the latter are liable to be subjected to high pressure. For concrete likely to be exposed to humidity (in foundations) or to violent shocks (in fortifications) it may be advisable to add grease or oil to the cement paste during the building. For the complete article is claimed a resiliency that will resist the disintegrating action or vibration of violent shocks, but its success has yet to be proved by practical experience.



RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

THE CONCRETE INSTITUTE.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE CONCRETE INSTITUTE.

THE CHARTERHOUSE STREET COLD STORES OF THE PORT OF LONDON AUTHORITY.

By H. J. DEANE, B.E. (Sydney), M.Inst.C.E., M.Inst.M.E.

The following is a short abstract of a paper recently read before the Concrete Institute. By the courtesy of the Concrete Institute we are able to reproduce a few of the illustrations which were given in connection with the paper. A short report of the discussion is also given.

INTRODUCTORY.

Soon after the Port Authority came into being it became apparent that the West Smithfield Store was inadequate for the requirements of the trade and that further facilities in the way of cold storage were an urgent necessity.

The absence of a more suitable site ultimately led to negotiations being concluded with the City Corporation for the lease of an area of about 17,100 super ft. on the north side of Charterhouse Street, immediately opposite the Central Markets and situated over the railway connecting Farringdon Street and Snow Hill Stations.

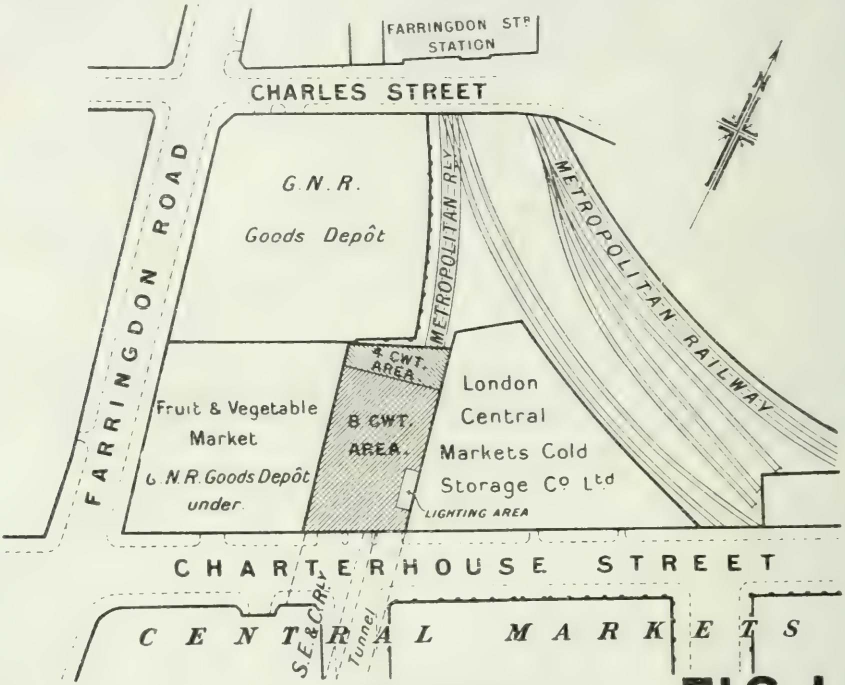
The site, from an engineering point of view, is probably one of the least desirable that could be conceived. It consists of a raft or platform constructed of built-up steel girders (varying from $39\frac{1}{4}$ in. by 18 in. to $40\frac{3}{4}$ in. by 24 in. and spaced 8 ft. apart), with brick jack arches and concrete filling between. With the exception of those on the eastern side, which are carried directly on to stanchions, the cross-girders are supported on three rows of main girders of varying dimensions which are in turn supported by steel stanchions encased in concrete. The spacing of the main stanchions is governed by the position of the permanent way of the three railway companies over which the platform has been constructed, as well as by other local conditions.

The allowable loading of the platform is necessarily limited to that for which it was designed, and the terms of the lease prohibit the imposition of any greater loading than the 8 cwts. and 4 cwts. per ft. super over the areas shown in *Fig.* 1. These limitations were responsible for a good many of the most interesting features in the design of the building which now stands upon that area.

Fig. 5 shows a section through the cross-girders of the platform, and the lines of the main girders are shown in *Fig.* 2 by the letters A.C., D.K., L.R. On reference to these drawings, it will be obvious that all concentrated loads had to be arranged either to come directly on to the girders or be transmitted thereto by means of distributing girders or grids, and this is responsible for what would otherwise appear to be an unusual arrangement of the columns. Under such conditions the designing of a building, which not only had to satisfy these limitations, but had also to provide facilities for loading and unloading, sorting to marks, office accommodation, handling appliances, engine-room space, combined with the largest capacity possible for the storage of produce, was a matter which required very careful consideration and a great deal of calculation before the final arrangement could be arrived at.

GENERAL DESCRIPTION OF THE COLD STORE.

The building generally is constructed of reinforced concrete, faced on the Charterhouse Street side with granite and Portland stone. It has three floors, in addition to the ground floor, the cold storage chambers being situated on the ground, first and second floors, whilst the top floor is utilised for sorting and distributing of produce and for office accommodation



— SITE PLAN. — FIG. I.

Scale of Feet.

FEET 100 50 0 100 200 300 400 FEET

The refrigerating machinery is placed at the back of the building on the ground floor level and occupies that area of the site which is limited to a loading of 4 cwts. per sq. ft. Access to the Machinery Room is given by means of a passage along the east side of the building, in which accommodation is also found for the storage of the ammonia bottles. The roof flat over the Machinery Room is of reinforced concrete construction, and access thereto is afforded by an iron staircase through a hatchway leading to the Ammonia Condensers, etc. (see *Fig.* 5).

On the Charterhouse Street side is provided, under cover of the first floor, a cart area and loading bank (see *Fig.* 2), from whence communication between this and the top or sorting floor is obtained by means of lifts and conveyors. This cart area is laid in asphalte, graded so as to be readily hosed down. There is ample space for ingress and egress of traffic from the street, the gateways being fitted with collapsible "Bostwick" gates, which, when open, are housed behind the granite columns. It was unfortunate that this area could not be unobstructed by columns, but the limitations of loading on the raft made it necessary to put in columns to distribute the weight from the floors overhead to the structure underneath.

A passenger lift is provided in the stair-well for the convenience of those having business on the top floor.

The top floor, in the main, is covered by a north light roof which has the advantage of affording excellent lighting without letting in the direct rays of the sun and thereby raising the temperature of the sorting floor.

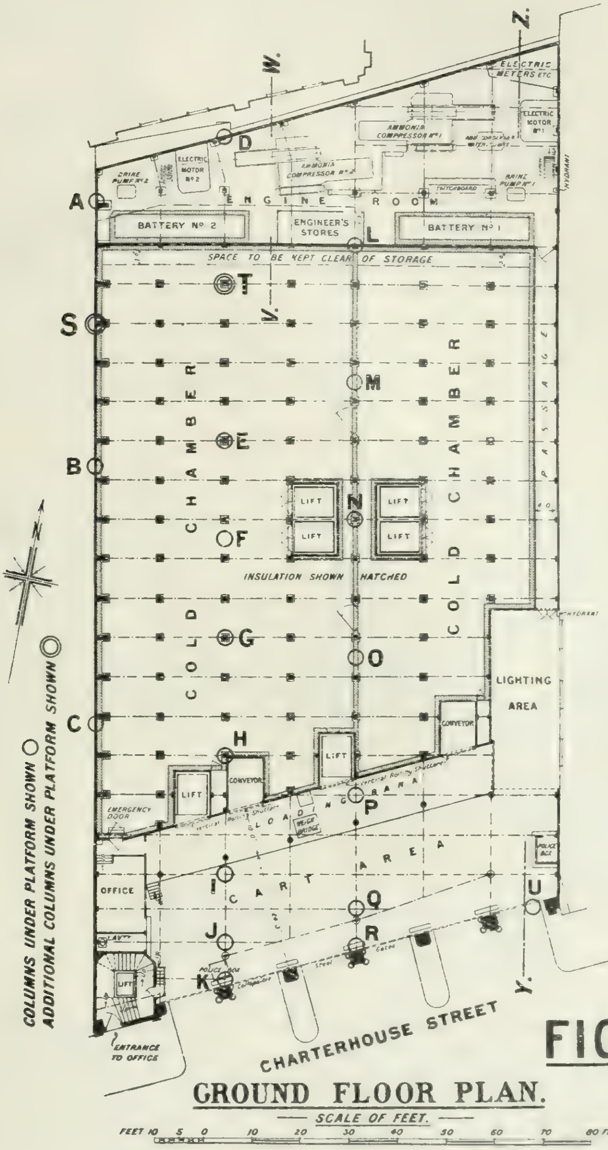


FIG. 2.

GROUND FLOOR PLAN.

The six cold chambers are arranged so that in normal working, access thereto is obtained only from the top floor. This arrangement has great advantages in economy in running, the cold heavy air being always retained in the chambers, whether produce is being moved in or out, whereas in the old type of chamber with doors or portholes at or near the floor level the cold air pours out and warm air goes in to take its place whenever the doors are opened. Another advantage is that sorting to marks can take place on one floor where there is ample space and good lighting, and under proper supervision. The offices are light and airy, and are divided from each other generally by glazed partitions, the floors being laid in maple blocks so as to afford a non-conducting medium on top of the concrete floor, under which are the cold chambers. Heating of the offices is by low pressure hot water, gas heated. A pneumatic tube for transmission of "delivery notes," etc., connects the main offices with the small delivery office on the ground floor.

It should be mentioned that in each of the three cold chambers there is a door at the south-western corner which can be used in case of emergency; these doors are readily opened from the inside, but access from the outside can only be obtained by means of a key which is kept in a glass-faced box near by.

The total contents of the chambers are approximately 386,900 cu. ft., and after making due allowance for the dead loads, the total number of carcases of sheep, taken at an average of 56 lb. per carcase, which can be stored is 78,000 (equivalent to about 4.99 cu. ft. per carcase including gangways).

If the building had been required strictly to conform to the regulations made under the London Building Acts, the floors would have had to be designed to carry "warehouse" loads of 224 lb. per sq. ft. This would have so greatly reduced the allowable live loading that the storage capacity would have been reduced below the point at which the Stores could be made to pay. As it is, the ultimate capacity of the Store is some 6,000 carcases less than was originally anticipated, when negotiations with the Corporation were first entered into.

THE CONSTRUCTION OF THE BUILDING.

Tenders for the construction of the building were received towards the end of July 1912 on outline designs, specifications, schedule of prices and approximate bill of quantities prepared by the Port Authority.

The tenderers were free to submit any system of reinforcing which they considered most suitable and, under the contract, were to be held responsible for the sufficiency of their designs. They were not permitted to make any variation from the positions of the columns and beams, and were required to conform strictly to the limits of loading specified. Owing, however, to unforeseen delays, arising mainly out of the difficulties in settling the question of loading and storage capacity, it was not possible to accept any tender until May of the following year, when the order was placed with Messrs. Trollope & Sons and Colls & Sons on designs prepared by Dr. Oscar Faber.

Prior to actually commencing work on the construction of any of the columns or walls, the surface of the raft was opened up in order to ascertain the exact positions of the main and cross-girders on which the concentrated loads were to be placed.

Owing to the necessity for obstructing as little as possible the space allowed for the cart area, it was decided to substitute, in place of reinforced concrete, nine solid steel columns varying from 6 in. to 7 in. diameter, 12 ft. 8 in. long, shod top and bottom with solid steel blocks about 18 in. square by 4 in. thick. These columns were subsequently protected against abrasion damage by oak casing, bound with steel hoops, extending 5 ft. above the ground level. On the loading bank the columns were encased in concrete, which was protected against damage by steel casing extending about 6 ft. up.

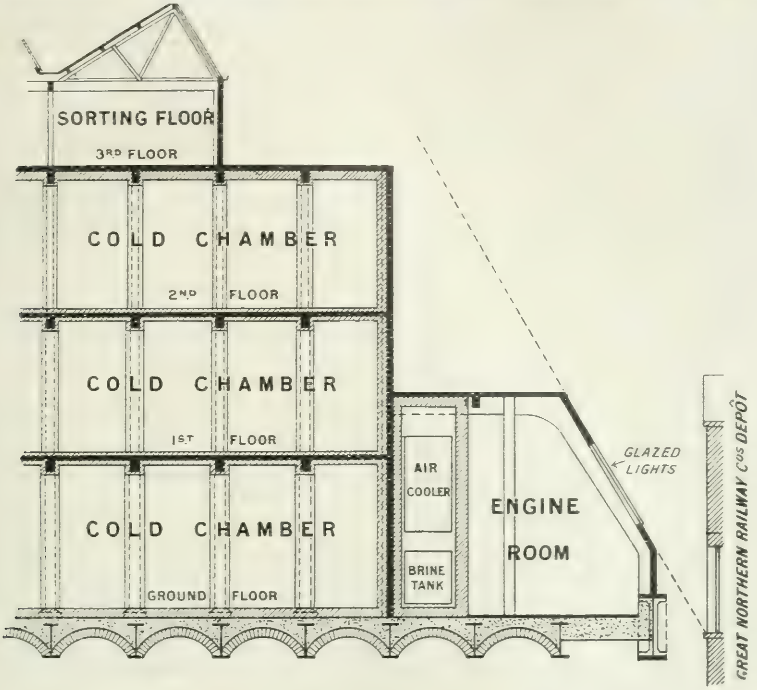
Reference is made in the earlier part of the Paper to the Great Northern Railway Company's claim to right of light and air. The position of its premises, on the northern side of the site, is adjacent to the west end of the Machinery Room. The platform already cut off a certain amount of light from the windows, and by constructing the outside wall of the Machinery Room in the manner shown in *Fig.* 6 the natural lighting was not entirely obstructed. The sloping wall is provided with a large glazed area, which affords a considerable amount of the natural lighting to the Machinery Room; further lighting, as well as ventilation, is provided by two raised skylights fitted with louvres.

Portions of the second and third floors are also covered with flat roofs, but the main area of the latter is covered with Bangor slates on thick roofing felt laid on 1 in. boarding and supported by steel trusses. These trusses are carried on reinforced concrete construction built up for that purpose above the top floor level.

The specification required the contractor to provide in his design for all columns, counterforts, and pilasters being constructed in the precise positions shown on the outline drawings, and beam construction was restricted in the main to a direction transverse to the length of the building. The walls were specified to be 6 in. thick.

In designing the reinforced concrete work the weight of the reinforced concrete was taken at 150 lb. per cu. ft. and insulating materials at 18 lb. per cu. ft.

The live loads to be provided for were 40 lb. per sq. ft. on a horizontal plane for the pitched roof (this included the dead load of the roof itself), 56 lb. per sq. ft on all flat roofs, $1\frac{1}{2}$ cwt. per sq. ft. on first and second floors, and 1 cwt. per sq. ft. on the third floor. All walls were to be considered as subject on each side to a uniform pressure of 40 lb. per sq. ft. on the whole area. The worst possible combinations of the above loadings were to be taken in arriving at the maximum stresses. Generally speaking, the methods and formulæ outlined in the second report of the R.I.B.A. Joint Committee on Reinforced Concrete, dated 1911, were to be adhered to.



INSULATION SHOWN HATCHED. **FIG. 6.**

SECTION V.W. (SEE FIG. 2).

SCALE OF FEET.

FEET 10 5 0 10 20 30 40 50 FEET

The concrete for the reinforced concrete construction was composed of clean crushed Thames ballast passed through a ¾ in., and retained on a ¼ in. screen mixed with Ham River grit in the proportion of 2 to 1 with latitude for variation when necessary so as to ensure the whole of the voids being properly filled. The cement used was in the proportion of one bag of 224 lb. to every 4½ cu. ft. of sand, and complied with the requirements of the British Standard Specification, the initial set being between 50 and 90 minutes and the final set between 5 and 7 hours.

The beam moulds were so arranged that the sides were readily removed without disturbing the bottom until the beam was sufficiently set, the camber allowed for in the moulds being 1/300th to 1/360th of the span, according to the dimensions of the beam. The column moulds were all arranged with one open side, and this was built up as the concreting proceeded. The steel reinforcing bars were of plain circular sections, having an ultimate strength of 28 to 30 tons per sq. in., an elongation of not less than 20 per cent. in 8 in., and otherwise generally conformed to the British Standard Specification. These bars were covered with at least 1 in. of concrete in the case of beam columns, etc., and ½ in. in the case of the floor slabs, except where such slabs were in contact with the insulation, when not less than 1 in. cover was provided.

The minimum time allowed before removing the supports from the reinforced concrete was, in the case of the main beams and floors, 14 days, and in the other cases 8 days.

The maximum test loads to be applied to the floors and beams provided for an excess of 50 per cent. over the live load for which the particular portion of the structure was designed, and the resulting deflection was not allowed to exceed 1/600th of the span.

Reference was made in the earlier part of the paper to the granite and Portland stone facing on the Charterhouse Street side. The lower portion of this facing was executed in Cornish granite, fine axed, and consists of piers and arches forming the entrances and exits to the cart area and main entrance. This granite work was carried up to the level of the first floor, above which rubbed Portland stone facing from the Whit bed was used. This facing work, which varies from 3 in. to 6 in. in thickness, is backed by the reinforced concrete wall, for which it formed the outer shuttering.

Some doubt was felt as to the possibility of the Portland stone becoming stained as a result of the gradual absorption of some of the constituents from the cement in the concrete backing. The usual method, however, of avoiding this trouble, by covering the surface of the stone with limewash, could not be applied, as it was most essential to obtain as complete a bond as possible between the two materials. It was accordingly arranged that, before placing the concrete, the stone should be thoroughly wetted and allowed to absorb as much water as possible, after which the concrete, mixed with as little water as possible, was filled in behind and well rammed. The effect was that, in setting, the concrete tended to draw moisture from the stone, and not, as would otherwise have been the case, the stone drawing moisture from the concrete by capillary attraction.

The result up to the present has been most satisfactory, no appearance of cement staining being visible.

It will be readily understood that the erection of a building of this description, which contains so much machinery and so many appliances as well as insulation of the cold chambers and cold air circulating arrangements, was not by any means a straightforward matter, and it was necessary in consequence to provide a ready means of access both for the erection of the refrigerating machinery at the rear of the building and for the fixing of the insulation, etc., inside the chambers. This was allowed for by temporarily omitting two panels in the walls of the ground floor, one adjacent to the loading bank and the other immediately opposite in the wall separating the Machinery Room from the Cold Chamber. These openings were subsequently filled up when the need for them had disappeared. In anticipation, however, of possible future difficulties in getting long scantlings into the cold chambers should the necessity ever arise, it was decided to construct a porthole in the wall adjacent to the loading bank. This porthole can readily be reopened and long scantlings passed directly through into the Cold Chamber from the street level, and thence up through one of the lift wells to any of the upper floors ; a properly framed insulating plug is provided on the inside over this porthole, so that the insulation will not have to be cut into.

One of the noteworthy features is the way in which the loads at the front of the building are carried. Owing to the peculiarities of the design of the platform on which the building rests, the front columns supporting the building could only be placed in certain positions, which vary from 27 ft. to 29 ft. centres; although above the first floor, columns had to be provided at about 15 ft. centres to keep down the depth of the beams.

To meet this, a continuous reinforced concrete beam was constructed along the whole front, 14 ft. deep and 12 in. thick, completely filling the panel between the first and second floors, and carried on three reinforced concrete columns. Under the centre of each of the three spans a granite column was constructed purely for architectural effect, exactly similar in appearance to the granite-faced reinforced concrete columns which carry the large beam, but no weight is taken by them on account of the loading restrictions. These columns are calculated to carry a load of 355 tons, which is transmitted directly on to steel girders without any footings.

The steel columns in the cart area, referred to earlier in the paper, are continued above as concrete columns, as the necessity of reducing their dimensions to a minimum did not arise. Under London County Council Regulations, this arrangement would have been impossible, as the requirements of the Building Act in respect of steel-frame construction and the Reinforced Concrete Regulations cannot be applied at the same time in any one building.

The absence in the reinforced work of cracks due to the large divergence of temperatures to which the structure is subjected is remarkable, but is no doubt due to the effect of the insulation, although the outside of the walls is cold to the touch.

Beyond these special points there is little that calls for remark in respect of the reinforced concrete work.

Fig. 7 gives typical elevations and sections of beams and columns.

ADDITIONAL SUPPORTS UNDER PLATFORM.

Soon after the Stores were opened for the reception of carcases, and loading commenced several cracks made their appearance in the external walls at the back of the building. From the nature and direction of these cracks it was concluded that they were due to the deflection of certain of the longer main girders forming part of the platform on which the building had been constructed. Further loading on the area affected was thereupon stopped for the time being.

At the north-west corner of the site and under the walls in which the cracks appeared the existence of a locomotive fan turntable and a sewer had resulted in an arrangement of stanchions which necessitated two of the main girders being constructed to spans of 61 ft. 10½ in. and 54 ft., with an overall depth of 6 ft. 8¾ in. and 5 ft. 5 in. respectively. Calculations showed that whilst of ample strength, deflection must occur in these girders to the extent of about 15/32 in. and 27/64 in. due to the dead loads coming on them, and a further 9/64 in and 11/54 in. respectively due to the allowable live loads.

Further, it was ascertained that the deflection varied according to the variation in the number of carcases in the store. In view of the fact that the weather could reach the insulating material unless the cracks in the walls were permanently closed, it became necessary to stop the variation in the amount of deflection of the two girders.

Permission was therefore obtained to erect two additional stanchions under the girders, approximately midway between their points of support. The positions of these are indicated in *Fig.* 2 by the letters T and S.

The new stanchions, which were built up of rolled steel joists and plates, were designed to carry loads up to 400 tons and 253 tons respectively, and were placed on foundations consisting of grillages of rolled steel joists embedded in 6 to 1 P.C. concrete carried down on to the London clay the loads on which were arranged so as not to exceed 4 tons per sq. ft. In the meantime, two 1¼-in. steel plates, drilled to template for the accommodation of the rivet heads on the underside of the girders, had been secured thereto with a layer of 7 lb. lead interposed between the plate and the girder in each case. Two pairs of folding steel wedges, 3 ft. 6 in. long by 8 in. wide, with a taper of 1 in 42, were then placed in position on the top of each stanchion and immediately over the flanges of the stanchions, and all four were driven simultaneously from a staging with 14-lb. hammers. Previous to driving up the wedges the live loads on the areas carried by the girders in question were reduced as much as possible, and the wedges were driven until the whole of the deflection due to the remaining live load and a small amount of the deflection due to the dead load were taken out, thus preventing the possibility of any further movement in the future.

The stanchions were wrapped with expanded metal and encased in concrete to preserve them against deterioration.

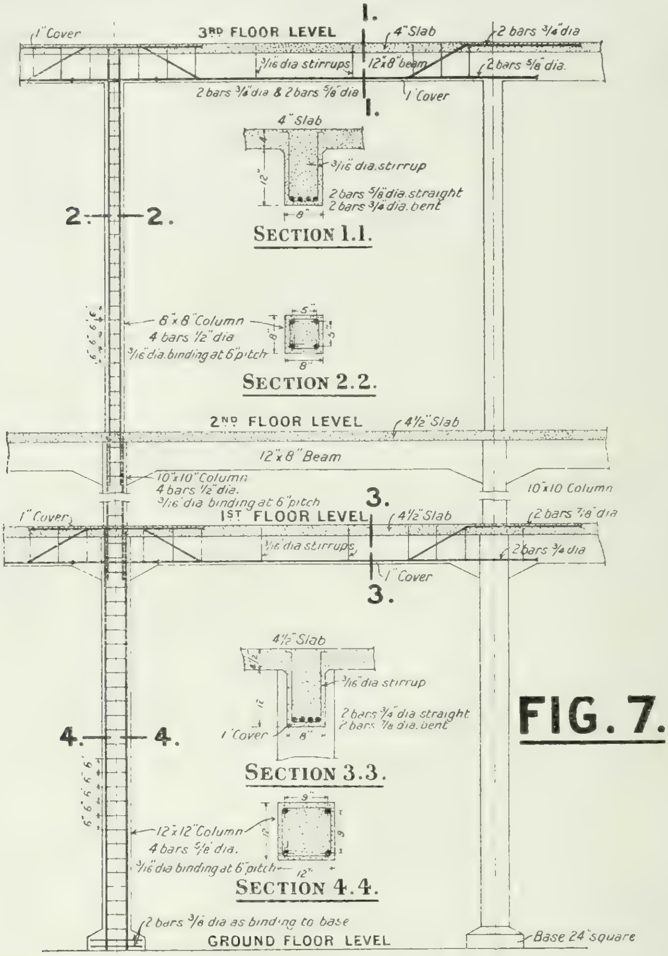


FIG. 7.

REINFORCED CONCRETE DETAILS.

After the completion of this work an internal examination of the condition of the insulation in the neighbourhood of the cracks was made by opening out the linings, but fortunately no deterioration was discovered. The cracks in the walls were accordingly cut out and filled with cement, and no further movement has since been discerned.

The whole of the work was carried out under the direction of Mr. C. R. S. Kirkpatrick, M.Inst.C.E., who early in 1913 succeeded Mr. F. Palmer, C.I.E., M.Inst.C.E., as Chief Engineer to the Port of London Authority, the author holding the position of Chief Assistant Engineer since July, 1913.

Valuable assistance was given by Messrs. Esplen, Son, & Swainston, who acted as consulting specialists in respect to the refrigerating machinery and insulation, and by Mr. T. H. Smith, consulting architect for the building.

The author desires to acknowledge his indebtedness to Mr. W. B. Statham, Assoc.M.Inst.C.E., of Messrs. The Lightfoot Refrigeration Company; Dr. Oscar Faber, D.Sc., Assoc.M.Inst.C.E., Member of the Concrete Institute; and to the various members of the Authority's staff who have rendered valuable assistance to the author in the preparation of this paper.

DISCUSSION.

Sir Henry Tanner, in moving a vote of thanks to the reader of the Paper, said the construction seemed remarkably good, and reinforced concrete most useful for the purpose.

Mr. C. R. S. Kirkpatrick, M.Inst.C.E., considered that much of the success of the cold store was due to the skill with which Mr. Deane had carried out the work. It was contemplated first of all that it would hold 84,000 carcases, but the number was reduced to 78,000. The District Surveyor of the London County Council claimed that it came within the London Building Regulations, and if that contention had been maintained, the store in 1911 would have had to have been constructed of brickwork, and that would have involved the taking off of one storey, owing to the fact that it had to be built on top of tunnels. The 1909 Building Act Regulations required 2 cwt. per sq. ft. of each floor and a load of 4 cwt. per sq. ft., and if these had been complied with the store could not have been built, and the number of carcases stored would have had to be reduced, which would not have been satisfactory from a financial point of view. But there was generally a way of getting over these difficulties. The Corporation of London Central Markets Act contained an exemption from the Metropolis Building Act of 1855 for all buildings required for, or in connection with, meat, and taking advantage of this exemption, they were able, ignoring the L.C.C. Regulations, to put up the building of one storey higher. Excluding the foundations and the raft the cost came out at 3s. 4½d. per cu. ft. of refrigerating space, excluding the machinery space, which was equivalent to 11s. 9½d. per carcase of mutton.

Dr. Oscar Faber, D.Sc., referring to the danger of the cracking of the walls from the great reduction of temperature owing to the refrigerator inside, after a certain amount of discussion they came to the conclusion that the question of contraction and expansion meant very little, and eventually not very much reinforcement of the walls was made. The L.C.C. Regulations required the floors to be designed to carry 224 lb. per ft.; but, as a matter of fact, they were actually designed for 168 lb. in the case of some and 112 lb. in the case of others. The wall carrying the building three or four storeys was only 6 in. thick, but if the L.C.C. regulations had been observed, they would have had to provide concrete columns all round the wall to carry all the load, apart from the walls, and that would have added considerably to the weight and the expense, besides being unnecessary. It would be well to consider whether they should allow such a very large sum to be wasted in such buildings. The use of Portland stone on the front of the building through which the cement had not penetrated he should be glad to have explained. If they adopted the later regulations, he maintained they tended to give them too strong beams and too weak columns. Maple block flooring, although it had many very excellent properties, he considered rather dangerous to use in cold storage buildings.

Mr. W. B. Statham, Assoc.M.Inst.C.E., pointed out that the condensers were specially designed to economise water, which was very important in a town where water had to be paid for, as it reduced the water consumption by 90 per cent. Moreover, the condensers had the further advantage that they were always easily accessible.

The Lecturer's Reply.

Mr. Deane, in reply, thanked the Institute for their cordial reception of his Paper. Referring to Dr. Faber's criticism of the bending moments in the specification, he had to say generally that if the structure had been cut down, if the bending moments had been reduced, he thought probably they should have asked for a little more concrete to protect themselves against the possibility of the effect of the cold on the reinforced structure. He did not think the sum total would have meant very much in carcases, and after all carcases were the thing that the store existed for. The action of cement on Portland stone had been rather a hobby of his for some years. He had seen many buildings where the Portland stone had been absolutely ruined by the use of Portland cement too wet and the stone too dry, and the inevitable staining had resulted. As to the use of maple block flooring, if there was any moisture about it would soak it up. The space that was allowed was 1½ in. all round, but if he were laying maple block flooring on concrete again, he would probably increase the space to 3 in. all round. It had a habit of pulling up; but after it once settled down it never gave any further trouble, and made an excellent flooring. He sympathised with Dr. Faber's criticisms of the L.C.C. Regulations as regarded loads, as they appeared to him to be just. The most prominent feature about the methods of design adopted in this case, compared with the methods imposed by the Building Regulations, was the fact that the building was standing to-day; there was no sign of it giving way anywhere. If those building regulations were the minimum, it seemed to him there was something wrong somewhere. They made several experiments on the weight of carcases to see exactly how they could load up the floor, and they came to the conclusion from the tests made that the average weight per New Zealand sheep carcase was 54·4 lb., and the cu. ft. space occupied was 2·266, and the average weight of a quarter of beef was 153·2 lb., and it occupied 7·554 cu. ft. of space.

CORRESPONDENCE.

Under this heading we invite correspondence.

PERMEABILITY OF CONCRETE OIL MIXTURES.

To the Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

SIR,—As the following tests in the above direction may be of general interest, I am sending you particulars. Possibly many other experiments have been made in the same direction, and with which these results may be compared.

The feature of the test was to introduce a quantity of kerosene into the mixture after the water had been added and the batch thoroughly mixed; it was then well churned up and moulded straight away. During the handling the oil was steadily rising through the mixture, and continued to drain off for a period approximately as long as the concrete took to attain its initial set. The quantity of kerosene used was 10 per cent. of the volume of water required for the mix, which was of medium consistency.

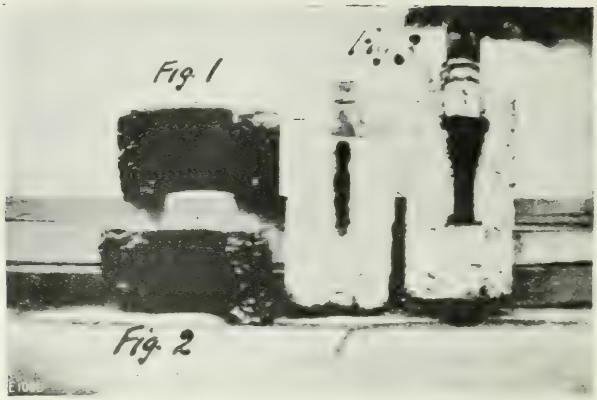
Several hollow cylinders were moulded with a mix of 1 : 2 : 4. The cement was a reputable English brand. The sand was an indifferent sample of fine stuff; it was necessary to wash the organic matter from it. Its composition, when washed, was: Held on a 20 sieve, 20 per cent.; held on a 30 sieve, 45 per cent.; and held on a 76 sieve, 30 per cent.; discarded through the 76 sieve, 5 per cent. The stone was good angular bluestone, and it was screened through a ¾-in. sieve, and the dust and finer particles removed with an ⅛-in. sieve. The stone was well wetted and allowed to drain over night before using. The concrete was mixed to a medium consistency, and cylinders shown in *Figs.* 1 and 2 were moulded. To the remainder of the batch of concrete was added kerosene in as near as could be estimated 10 per cent. of the water used. The batch was again well churned, and the cylinder shown in *Fig.* 4 was moulded. No reinforcements were used. After 36 hours the moulds were removed and the cylinders were buried in damp sand. Three weeks later they were removed and dried in air. Cylinders shown in *Figs.* 1 and 4 were then subjected to a water pressure of 40-ft. head. *Fig.* 1 soon absorbed a lot of water, and showed dampness on the outer face. *Fig.* 4 showed neither sign of absorption or dampness, the loss in the tube above being no more than might reasonably be accounted for by evaporation. The two cylinders were under pressure and observation for a period of three weeks. It should be mentioned that the walls of the cylinders were 3 in. thick, *Fig.* 1 having an inner diameter of 6 in., and having its face rendered or floated ½ in. thick with mortar composed of cement in 1 part to 2½ parts of sand. The inner diameter of cylinder shown in *Fig.* 4 was 1½ in.

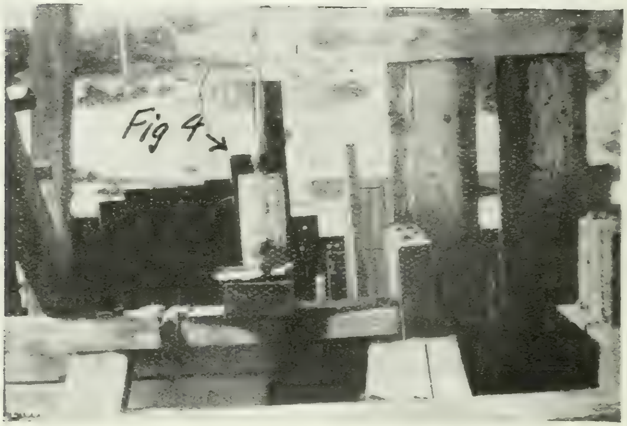
Cylinders shown in *Figs.* 1, 2, and 4 were then dried again and then subjected to a 40-ft. head of pressure of residual oil. *Figs.* 1 and 2 soon showed signs of oil sweating through the walls. *Fig.* 4 was left under this pressure for two years, and, as can be seen in the print, remained absolutely impervious. *Fig.* 4 shows the cylinder in position: the dark patch on the bottom is an oil stain on the outer skin, caused by careless handling of the oil when filling the cylinder. The picture shown by *Figs.* 1, 2, and 3 shows the cylinder split after the test. In *Figs.* 1 and 2 it is plain that the oil has soaked entirely through the walls, while in *Fig.* 3 it can be seen that the oil has not entered the concrete in the least degree. The broad, black marking in the right-hand half of *Fig.* 3 was caused by a small quantity of residue being left in the cylinder, and when it was being split the oil ran over the face to some extent; that it is not incorporated in the concrete can readily be seen by viewing the other broken face of the cylinder.

With a view of obtaining an idea of the effect of the oil upon the strength of concrete, a number of briquettes were made up in neat cement, and in cement treated with the addition of 10 per cent. of kerosene.

After 28 days they were broken with the following results:

Neat cement, average tensity	644 lb.
Cement treated with oil, average tensity	667 ,,





Tests were also made for absorption in the following manner: Cylinders were made in the Vicat mould, and after being cured and dried under similar conditions, they were submitted to a pressure of 80 ft. head of water; after being left in this condition for six days they were removed, dried with a chamois skin, and immediately weighed, with the following results:

	Weight before Pressure.	Weight after Pressure.	Percentage of Increase.
Neat cement	0·925 lb.	0·95 lb.	2·7 %
Cement treated with oil	0·95 lb.	0·9562 lb.	0·65 %

E. P. Henshaw.

Henderson Naval Base, West Australia.

WIND PRESSURE ON ROOFS.

To the Editor of Concrete and Constructional Engineering.

Sir,—I hesitate to make the sweeping assertion that common practice and all our text books are wrong, but there is a matter I should like to see explained.

Taking the example given in Mr. Marsh's comments on the Sydney Reinforced Concrete Regulations in your May number, it seems to me that 40 lb. per sq. ft.

normal to the vertical plane is the total wind acting on 2·9 sq. ft of sloping surface (20°), and the 13·7 lb. component is distributed over 2·9 sq. ft., giving 4·73 lb. per sq. ft. instead of 13·7 lb. per sq. ft.

Yours, etc.,
D. W. R.

Mr. Chas. F. Marsh's Reply to above.

To the Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

SIR,—I beg to thank you for your letter of June 13th with enclosure criticising the statement with respect to wind pressures on roofs contained in my article on the Sydney Reinforced Concrete Regulations.

My statement is, I believe, substantially correct, since the wind pressure is of the nature of a fluid pressure, and consequently it is correct to consider it merely as an intensity of pressure, and not as a definite pressure acting on a definite area. Consequently the intensity pressure of 40 lb. per sq. ft. normal to the vertical plane should be multiplied by the sine of the inclination of the roof to the horizontal to give the intensity of pressure on the sloping surface, and not by the square of the sine as your correspondent suggests.

With respect to the general question as to the wind pressure on inclined surfaces, it might be pointed out that the generally accepted formula is one of an empirical nature based upon Hutton's experiments, this formula being as follows:

$$P_n = P(\sin \theta)^{1 \cdot 84 \cos \theta - 1}$$

where P_n is the pressure per sq. ft. normal to the inclined surface, "P" the horizontal wind pressure per sq. ft., and "θ" the angle of the inclined surface to the horizontal.

According to this formula the wind pressure normal to the inclined surface increases from nil for a flat surface until it reaches the same value as that on a vertical surface with an inclination of 57° 5′, which is generally assumed as 60°.

Yours truly,
CHARLES F. MARSH.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Concrete Ships in Italy.—The following question was asked in the House of Commons on June 3rd, regarding concrete ships in Italy :—

Mr. Percy Alfred Harris asked the First Lord of the Admiralty whether he would ascertain if sea-going barges of reinforced concrete, schooner-rigged, were in regular use for commercial purposes in Italy ten years ago ; whether he is aware that a 150-ton barge, the *Liguria*, was launched as far back as 1905, and has now been in regular commercial use for 12 years, and that the Italian Government concrete sea-going barges of 100 tons have now been in regular employment for a number of years ; and whether, having regard to the apparent lack of information as to concrete ships constructed in Italy, he will cause particulars to be collected of concrete ships, barges, and pontoons employed in the Mediterranean, the Adriatic, and the Italian rivers and ports with a view of obtaining information as to the experience in this Allied country, and making the same known to naval architects, reinforced concrete contractors, and shipbuilders in England.

Dr. Macnamara : Yes, sir, it is a fact the concrete sea-going barges of 150-ton capacity were constructed in Italy some ten years ago. I have no information, however, regarding the development of the construction of reinforced concrete craft in Italy, and so far as I am aware only a very small number is in use. We are, of course, glad of information at all times and from all sources. In recent years this industry had been widely developed in Scandinavia, and full reports as to the methods of construction, etc., adopted in that country have been obtained.

Dr. Macnamara, replying to Mr. P. A. Harris, said the large concrete ships recently launched on the Pacific Coast of America have been inspected by a British engineer, and his report is in the possession of the department concerned, which also possesses independent reports on these ships, while further reports are now awaited. When the information is obtained, which would, of course, include sea-going tests, and is comprehensive enough for the purpose, a report can be drawn up for the benefit of the British industries interested.

Concrete Floors and Enemy Bombs.—The following question was put in the House of Commons on June 3rd :—

Mr. Brace, Under-Secretary to the Home Office (Glamorgan, S., Lab.), replying to Mr. P. A. Harris (Harborough, L.), who asked whether any independent technical inquiry had been made as to air raid damage caused in January at the printing works of a weekly journal where many casualties resulted, said : I understand that inquiry has been made by technical experts appointed by the Committtee of Scientific and Industrial Research. The building had concrete floors over the basement, none of which were pierced by the bomb, which entered the building by a pavement light. The occurrence, therefore, affords no reason for doubting the utility of concrete floors as affording reasonable protection against blind shells, incendiary bombs, and explosive bombs of small size. I would remind the hon. member that the buildings available as air-raid shelters are not classified as bomb-proof, but they are quite suitable for the purpose for which they are primarily intended—namely, to afford shelter against splinters of bombs, shells, etc., for use by persons who happen to be in the open when the raid takes place.

Concrete Boilers for Ships.—A large ironworks firm in America—The Union Works—recently decided to test the feasibility of constructing concrete boilers for ships. In the opinion of the general manager of this firm, this form of construction would save 90 per cent. of the cost of construction. It is proposed to use a tube of light steel; around this there is to be a cylinder of concrete with straight cement in the centre and trumpet rivets to hold the whole together. The boiler is to be of the Scotch type.

Concrete Silos.—Messrs. James Scott and Son, 205 George Street, Aberdeen, have recently erected a reinforced concrete silo for Mr. James Cruickshank, Kilmarnock Arms, Cruden Bay, Aberdeenshire. This silo is constructed entirely of reinforced concrete, having 6-in. walls, 16 ft. diameter by 34 ft. high. The silo has almost continuous doors, also concrete roof with iron ladder up to same, and has a manhole on top for outlet; the water is carried from the roof in down-water pipes.—From *The Field*.

Concrete Cellars for Potato Storage.—A concrete potato cellar has been built on a farm at Maple Ridge, Midrigan, U.S.A. According to *Concrete*, U.S.A., from which particulars are taken, the cellar is built in a side hill, and is 25 ft. by 50 ft. by 9 ft. high, with a capacity of 4,000 to 5,000 tons. The roof is covered with several inches of earth. It has four rectangular openings, over which the loaded wagon is driven and the potatoes chuted to the bins. There is a side track to the front of the cellar, which affords economy in loading. It is stated that potatoes thus stored keep in excellent condition.

A Concrete Forge.—One of the most recent uses of concrete is in the making of blacksmiths' forges, says *Popular Mechanics*. A mixture of 4 parts gravel, 2 parts cement, and 2 of sand was used for the forge described by the writer, a most satisfying accessory.

The forms for the legs and hearth were built first. That for the hearth was built on to the leg forms, and the form for the hood was built on to the hearth form. The top of the forms of the hood and hearth was left open in each case to permit pouring and trowelling. The centre of the hearth is left about 4 in. lower than the edges. The form for the trough should be fastened together very lightly and held in position by several strips across the hearth form.

A galvanised-iron bucket is set in the hood to form the base of the smokestack. The bottom of the bucket is removed after the pouring.

A tuyère iron may be bought, or one made, and it should be placed in position in the form and the concrete run around it after provision has been made for holding it in place.

After the form is all complete the iron reinforcement is put in place. This may be made from old scrap iron, such as wagon tyres or round rod. Care should be taken to see that the reinforcements connect properly. No provision need be made for expansion and contraction caused by heating and cooling. This is taken care of automatically.

Volcanic Stone as an Aggregate for Concrete Ships.—"Concrete, U.S.A." states that some tests are being carried out with a light, but strong volcanic stone found near El Paso, which seems suitable as an aggregate for concrete ships.

Reinforced Concrete Coaling Station.—A new reinforced concrete coaling station has recently been completed on the Lehigh Valley, at Manchester, N.Y., which is notable not only because of the volume of storage space and capacity of the receiving and discharge facilities, but also because of a number of innovations incorporated in its construction. Duplicate receiving and hoisting facilities, an arrangement for mixing the various kinds of coal as received, and an unusual compactness and convenience in the installation are among the special features that deserve notice. The reinforced concrete storage bin is 70 ft. by 52 ft., and is elevated on concrete columns so as to serve locomotives standing on six sets of lines, four of which pass under the structure while one passes along each end. The elevating towers are separated from the bin structure by a distance of 39 ft., the coal being transferred from the tower to the bin by means of two bridges spanning the intervening distance and forming a part of the super-structure covering the top of the bin. The elevating equipment is in duplicate. Each elevating tower receives coal from a separate track hopper 20 ft. long, from which it is fed automatically into the elevating bucket by means of a

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STEAM FRICTION WINCHES

Illustration shows front view of a 6¼" × 10" "Zenith" Double barrel (tandem) Friction Winch. Note the ample space on the barrels to take the rope, the straight lead, the unobstructed view of the driver and easy control. These are only a few of the distinctive features of "Zenith" Winches.

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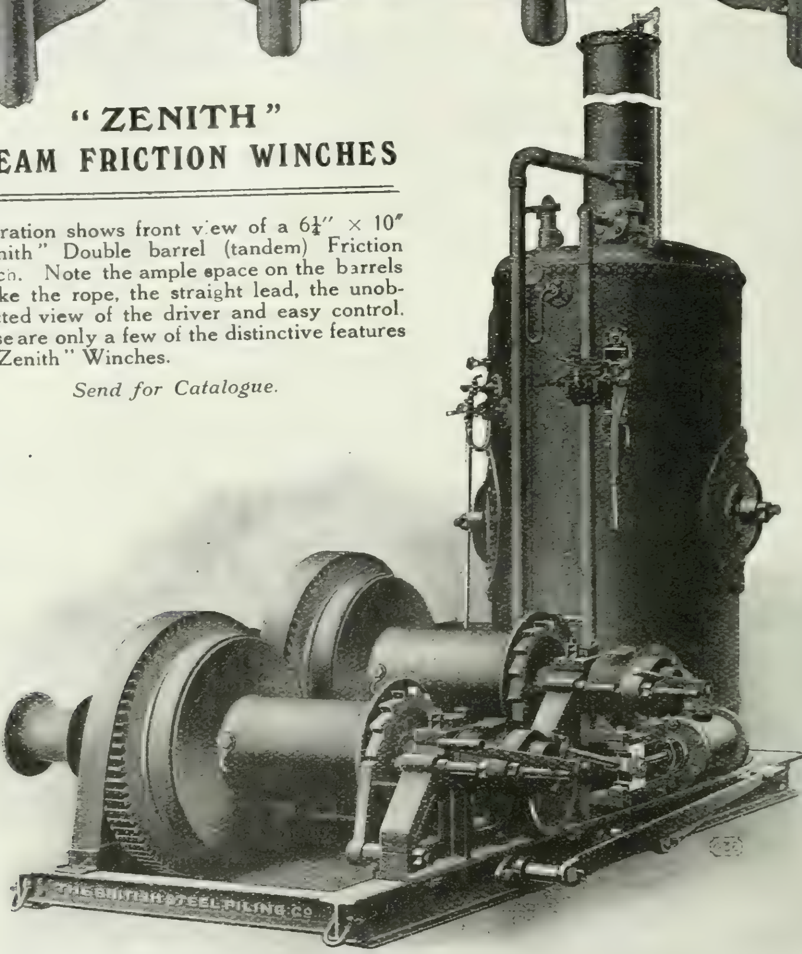


DOCK HOUSE, *Billiter Street*, LONDON, E.C.

measuring coal feeder of 2½ tons capacity, this feeder being actuated by the ascent and descent of the elevating bucket. The bucket in turn is raised and lowered by an independent electric hoist having a capacity of 75 tons per hour. Since there are two elevators, 150 tons of coal can be received from cars and distributed in the bins each hour. One of the chief advantages of this duplicate equipment is that the plant may be served by either of the hoists alone in case the other is out of service.—*Engineer.*

Tests of Cement, Lead and Metalium Joints for Cast-Iron Pipe.—More extensive use of cement joints for cast-iron pipe, especially at a time when lead is so costly, is indicated by recent tests made by Professor Frederic Bass, of the University of Minnesota, and J. A. Jensen, Minneapolis Waterworks, at the engineering laboratory of the University of Minnesota, the university and the city co-operating, and described in *Engineering News Record*, May 23rd. Four lengths each of standard cast-iron pipe, supported and connected, were tested. For the cement and metalium joints 8-in. pipe and for the lead joints 6-in. pipe were used, sufficient 8-in. not being available.

The lead joint was made in the customary manner.

The cement joint was made of Portland cement, mixed rather dry. The bell of the pipe was cleaned and a dry packing inserted. The inner half of the bell was filled and caulked with a blunt caulking tool without using a hammer. The outer half was filled with the same mixture and caulked with a hammer. A slightly wetter cement bead was immediately placed on the joint. The joint was kept covered with wet cloth for one week.

The metalium joint was poured in the usual manner and not caulked, and the material cannot be caulked.

In the 8-in. joints about 3·5 lb. of cement and 3·5 lb. of metalium were used. In the 6-in. joints about 11·5 lb. of lead was employed.

The water was allowed to fill the pipes after the initial set of the cement. Four days after the joints were made the water was let into the pipes under city pressure (75 lb. per sq. in.). At this time a test of the lead joint was made. The pressure was pumped up to 600 lb. per sq. in. without any visible result. The supports from the four middle lengths were removed and the pipe was deflected at the centre about 12 in., three joints opening, the middle joint to a very considerable extent, causing large leakage. These joints were then recaulked and remained tight at 600 lb. per sq. in. pressure.

The cement and metalium joints were tested 30 days after laying, and during this period the city pressure was kept on the pipes. The cement joints sweated slightly at first, the water which appeared on the surface evaporating. This soon disappeared and the joints, with the exception of one, became tight and dry. The wet joint was the first one put in. It was made with less water in the mixture than were the other joints. Ten days after laying a water pressure of 250 lb. per sq. in. was temporarily put on the cement joints, without visible result. During the 30 days the metalium joints all leaked, considerably at first, but less and less as the material of the joint became filled or expanded. The leakage at the end of 30 days under the city pressure of 75 lb. per sq. in. was at the rate of 260 gal. per mile of pipe (440 joints per mile).

At the time of the test the pressure was simultaneously increased on both pipes. It was held at 200 lb. per sq. in. and the leakage of the metalium joint was measured and found to have increased to a rate of 450 gal. per mile. No leakage from the cement joints was observed. The pressure was then increased to 300 lb. per sq. in. and the leakage from the metalium joints increased to a rate of 4,640 gal. per mile. The cement joints still showed no leakage. The pressure was again increased, but owing to leakage it could not be raised over 375 lb. per sq. in. The leakage was entirely from the metalium joints, the cement joints showing no leakage, but faint, radial hair cracks appeared in the upper third of the circumference on the cement bead. Later it was found that these cracks did not show in the joint itself.

The supports from the two middle pipe lengths were then removed (the pressure being maintained at 300 lb. per sq. in.), and both pipes deflected ⅜ in. at the middle joint. The supports were then removed from the next two pipes in both lines, and the deflection amounted to 3 (−⅛ in.). At this point two cement joints opened slightly, drops of water falling at intervals of about 10 secs. from each. The other cement joints remained tight. A load of iron of 850 lb. was then put across the middle of the two pipes, being equally divided between them. This caused the cement-jointed pipe to settle an additional $\frac{1}{8}$ in. and the metalium-jointed pipe to settle an additional $1\frac{1}{2}$ in.

It would seem from these tests that cement is a material which should be used for cast-iron water pipe except under the heavy pressures used for high-pressure fire service, or possibly under a fill where extreme settlement caused by a heavy filling, greater than that super-imposed in this test, would cause a much more severe bending load to be applied. A saving of from 5 to 8 per cent. of the total cost of an 8-in. pipe laid in an 8-ft. trench is apparent in the use of cement.

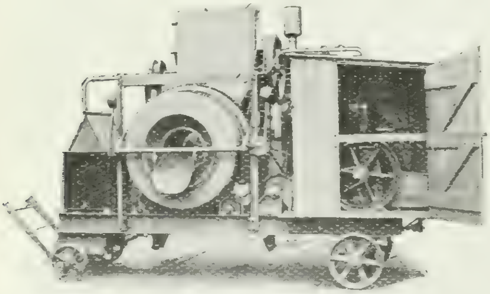
In all the joints here described the joints were made by experienced men, but possibly special care in handling the metalium was absent.

PUBLICATIONS.

The Concrete Utilities Bureau have recently issued five new pamphlets, entitled: Concrete Farm Buildings (No. 8), Concrete Troughs and Wells (No. 9), Concrete Greenhouses, Hot Beds, and Root Cellars (No. 10), Concrete in the Home (No. 11), and Concrete Blocks (No. 12). Copies of these pamphlets, which are fully illustrated, can be obtained at the offices of the Bureau, 6 Lloyd's Avenue, E.C.

TRADE NOTE.

Flooded Cellars.—The percolation of water into cellars after heavy rains can be prevented with absolute certainty, provided certain precautionary measures are taken. For instance, the sanitary engineer of the Alcester Rural District Council points out that one particular cellar, following every rainfall, was flooded for several days, sometimes to a height of about 2 ft. At first it was rendered with ordinary cement and the floor concreted, but without arresting the percolation. Then treatment with Pudloed cement was decided upon. The floor was concreted with a 6-in. layer of a 3–1–1 mixture with 3 lb. of Pudlo to every 100 lb. of cement, and then rendered with a 2 and 1 mixture of Pudloed cement, and the walls were rendered with a 2 and 1 coating $1\frac{1}{4}$ in. thick in 4 coats with 5 per cent. of Pudlo, the result being entirely satisfactory.



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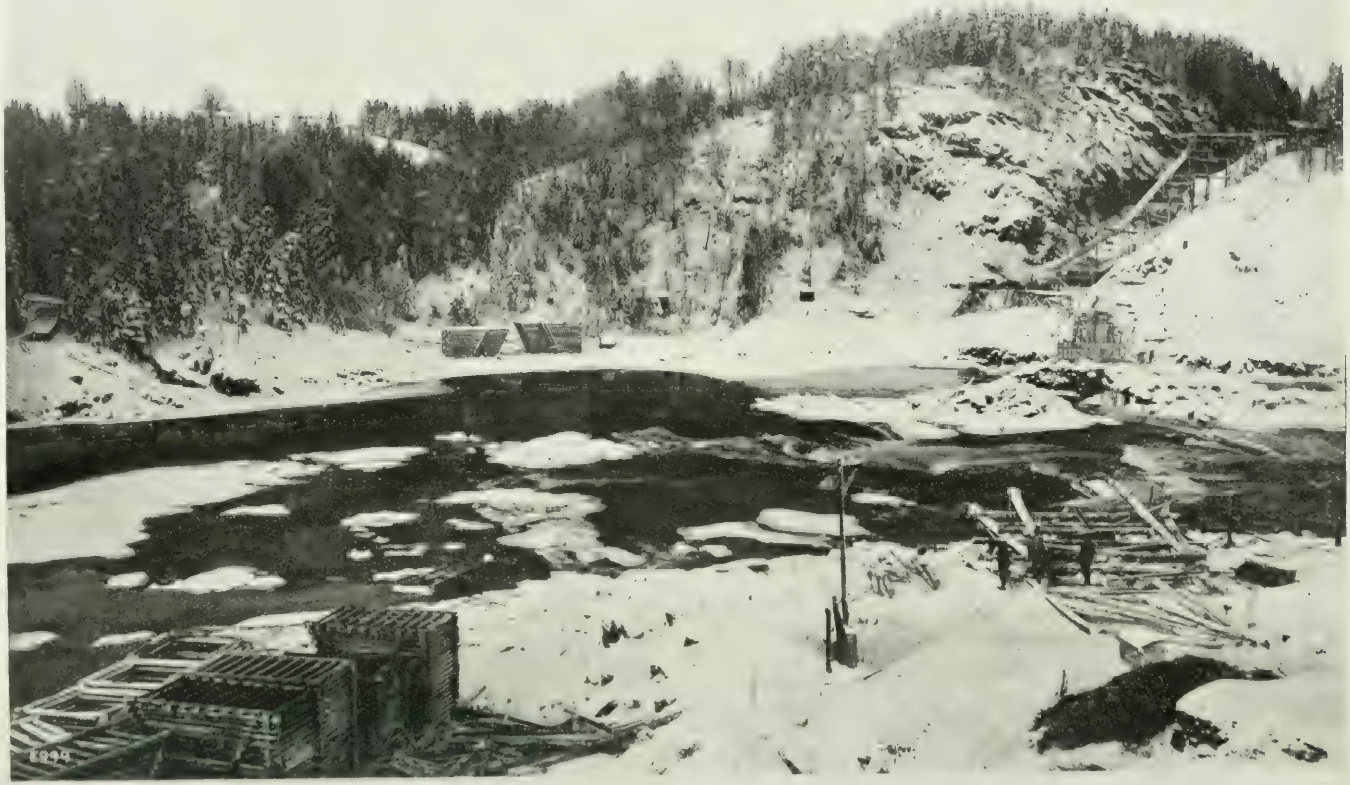


A General View of the Site showing Raft Boxes. Concrete Work at the Vamma Power Station.

(*For Description see page 387.*)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIII. No. 8. LONDON, AUGUST, 1918.

EDITORIAL NOTES.

AMERICA AND CONCRETE.

FROM time to time this journal gives particulars of individual works that are being carried out in the United States, where concrete and reinforced concrete take an important part in engineering and architectural works. But for some time we have not emphasised how great a rôle concrete is now playing throughout the American continent in all matters relating to civil engineerirg works and building construction, and that it is one of the primary factors in the technical discussions in the architectural and engineering societies.

To a large extent the development of interest in concrete in America has been a natural development, due to that progressive spirit that welcomes fresh ideas and new methods and is not fenced round with the prejudices, conservatism and regulations that prevent the rapid introduction of new methods.

But if this development has been natural, it has also been fostered to a great extent by the excellent work done by the American Concrete Institute under the energetic guidance of the leading members of its executive. In the American Concrete Institute we find no mere minor technical society concerned in debating academic questions, framing specifications, regulations and the like which, however useful to its membership and a number of professional men and industrial pioneers outside, have no bearing on the really great problems of the day. This American corporation does not confine itself to the so-called "details"; its primary function lies in assisting the development of concrete by popularising the subject, whilst at the same time giving every attention to the scientific aspects of its work and to the all-essential item of investigation. By popularising concrete the American Institute effects great national savings and increases national productivity. It simplifies and accelerates building construction and engineering works and puts concrete within the reach of everybody from the smallest of smallholders, and the smallest farmer, to the greatest estate owner and the greatest industrial or municipal corporation. The American Concrete Institute is a factor in the development of the structural work of the United States, a factor in the economy of the State, and now, during the war, a factor in winning the war.

ANNUAL MEETING OF THE AMERICAN CONCRETE INSTITUTE.

The Institute held its annual meeting on June 27th to 29th, and although naturally, owing to the times in which we find ourselves, the meeting was a comparatively small one, a large number of questions of vital interest at the present time were dealt with. We hope at a later date to be able to reproduce some of the papers read, but we should like briefly to refer to some of the subjects dealt with.

Considerable time was devoted to the all-important question of concrete roads and pavements, which has been practically neglected in this country except for a small amount of work which has been principally of an experimental character.

The problem of the concrete ship came in for a great amount of discussion, and bids fair to become an important development of the American Institute's activities.

Another important item to which attention was accorded was that of concrete housing and the building of the concrete house in hollow blocks and otherwise.

Research questions occupied considerable time, and there were papers dealing with individual features of design, the ornamental uses of concrete and the fire resistance of concrete, etc.

Altogether this may be considered an excellent programme of work, and combined with its pioneer work in pressing, for economic reasons, the advantages of concrete, and pressing these systematically, the American Concrete Institute has gained for itself a position of its own.

It is a pleasure to see what has been done by this body during the short period of its existence, and it would not be out of place if the example now so admirably set by the United States in these matters were followed at home for the benefit of structural development, of conservation and general economy in the British Empire.

CONCRETE WORK AT THE VAMMA POWER STATION, NORWAY.

For the following particulars and illustrations we are indebted to Mr. Geo. Brockner.—ED.

PRIOR to the construction of the Vamma Power Station the Vamma Fall was only utilised for the working of a village mill on the right side of the river. The fall, which is situated on the Glommen about 6½ km. below Kykkelsrud and about 32 km. above the Sarpsfoss, has a head of 27 m., with a regulated volume of water of 220 cu. m. per second, and the plant installed at the station is capable of an output of 36,000 h.p., which is being increased to give 60,000 h.p. To develop the power a concrete dam was constructed across the river at the top of the fall, the dam being 280 m. long, and the central portion, 160 m. long, was formed with 15 intake openings leading to sluice valves which are fitted to the upper ends of the turbine supply pipes. Arrangements were made for the valves to be laid dry when access is necessary to the sluices by means of large drains.

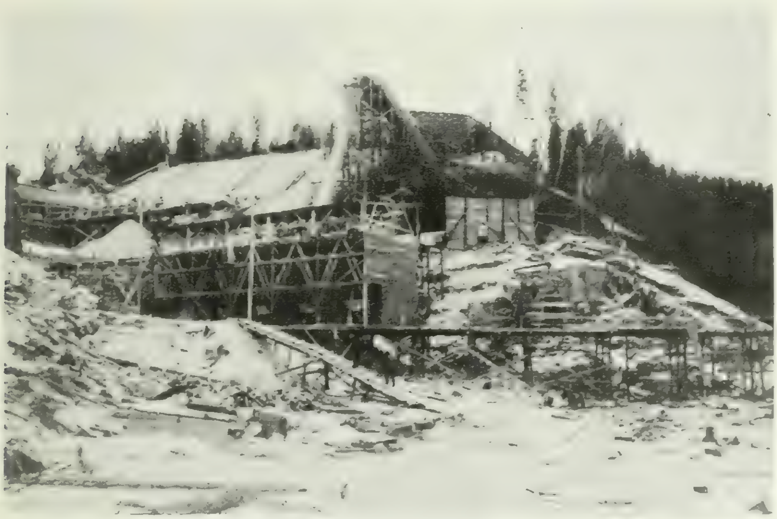


Fig. 1. View showing Concrete Mixing Plant.
CONCRETE WORK AT THE VAMMA POWER STATION, NORWAY.

The power station is situated at the down stream toe of the dam, to which it is parallel, and the transformer house is at right angles to the station and on the north side of it. Two roller weirs south of the station are provided to regulate the water level in the reservoir, and these form part of the weir over which the surplus water is passed.

The dam is constructed entirely of concrete and it rests everywhere on solid rock. Its greatest height is 38 m. and its greatest breadth at the bottom is 27 m., while the breadth at the crown varies from 4.40 m. to 7.60 m.

Several difficulties had to be overcome during the construction of this dam, and some notes as to the methods employed should be of interest.

CASTING THE CONCRETE.

The first casting of concrete took place during the winter 1907-8, when a needle dam was built from the right side of the river to the Vamma Stone, a rock, which at ordinary water level divided the river into two courses, the dam resting on square box rafts which were filled with stones. The plant was situated on the left side of the river, and for the purposes of transport a hanging bridge, with a span of 135 m., was built to form the connection between the left bank and the point of concreting.

The plant consisted of three English crushing machines and five mixing machines, the former being placed at a high level and some distance from the latter, with flying bridges between the two to form the connection. Direct rail service was provided between the mixing plant and the hanging bridge mentioned above for the rapid transport of the mixed concrete. The five mixing machines installed in the first instance were later replaced by two American machines of greater capacity. All the machinery was worked electrically, the necessary power being generated by a steam plant during the preliminary operations, and when the work was more advanced power was taken from a neighbouring power station. At the commencement of the concrete laying the stone for crushing was blasted from the rock at Rewnaasen, close to the crushing plant, and all other material had to be conveyed by horse and cart from the Askim railway station, a distance of about five kilometres. In consequence of the large amount of carting that was necessary—some fifty horses being in daily use—it was decided to construct a new road from the railway station to the site of the machinery and on the road rails were laid to facilitate the transport. The spring flood in April, 1908, interrupted the concrete work for a time, and during the following years up to and including 1911 the work proceeded slowly. The photographs, *Figs* 2 and 3, show the state of the operations in the early part of 1911.

In order to speed up the work, however, it was decided to improve the transport arrangements, and this was carried out in 1910: these improvements consisted of an ordinary gauge railway from Askim station to the Vamma top, with a connecting light railway, with haulage machinery, to the mixing plant, and a rope railway across the river. The latter was chiefly employed for the transport of the rock, when blasted, to the crushing machines.

GRADING THE AGGREGATES.

At about this time a plant was also installed for grading the aggregate in order to obtain a more even mixing. In the case of the coarse aggregate this consisted of a revolving drum, which received the discharge of the crusher, the drum having holes of 65 millimetres diameter, and the satisfactory material passed through these holes, while the rejected portions passed on to a second crusher placed in front of the drum, where it was again treated. The sand was also graded into three sizes by means of drums, these being installed in connection with a silo which was constructed for the storage.

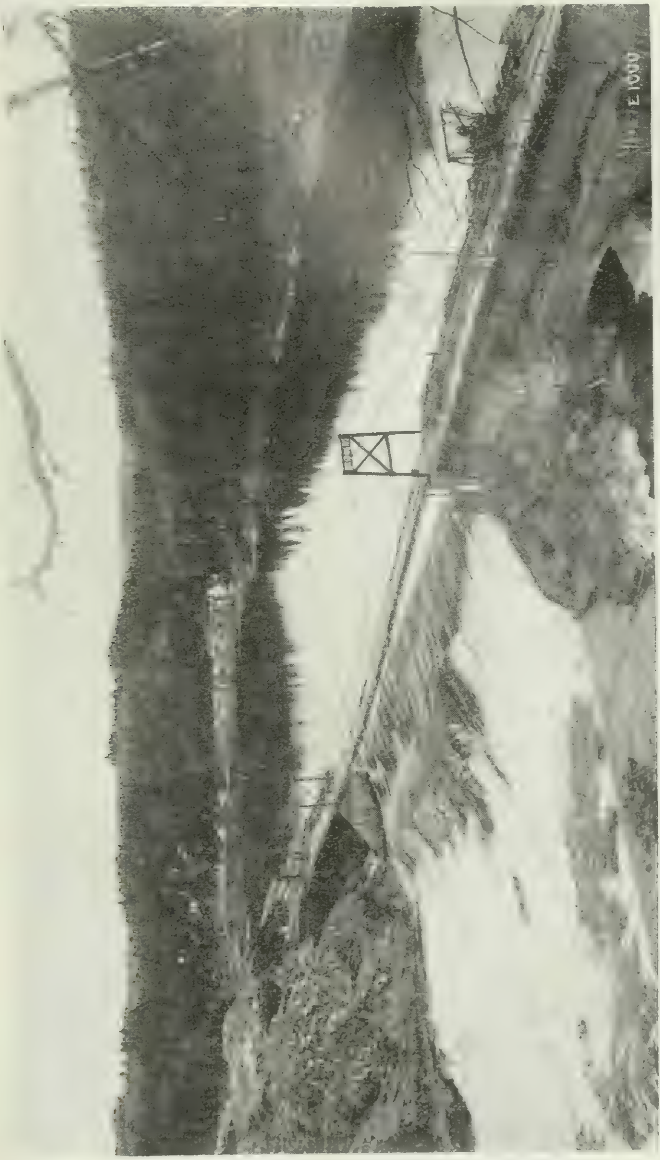


Fig. 2. View of Suspended Bridge.
Concrete Work at the Vamma Power Station, Norway.

The coarse aggregate was also washed by means of 1 in. diameter pipes, which were arranged to discharge under the jaws of the crushing machines so that the operation took place continuously after the crushing.

After the work had been speeded up the plant was destroyed by a fire which occurred at Easter, 1912, and a temporary plant had to be arranged to carry on the work during the following summer while a new plant was being installed. The work had so far advanced at the time that a hoist was necessary to raise the concrete, and the suspended bridge constructed in the first instance became useless, and a new one was built with a tower which allowed the roadway to be raised as the level of the work became higher.

CONCRETE ARCH AND DAM.

An interesting example of damming is shown in the photograph in *Fig.* 4, this being executed on the left side of the Vamma Stone in the year 1912 by means of a concrete arch. The proportions of the concrete for this work were 1 : 3 : 3 and the percussion strain was calculated at 22 kilograms per sq. centimetre. The mixing and crushing plant was increased in the spring of 1913 to facilitate the laying of the topmost portion of the permanent dam. The whole of the gauging for the concrete was done in special boxes fitted with hinged trap-doors, and the latter were arranged so that the proportions could be varied when desired.

As the casting of the dam proceeded the face course of the river was reduced. At the beginning of the winter 1914-15 the passage had been reduced to an opening 25 m. wide in the central portion of the dam, and when the casting of this section was commenced the water was led through the bottom openings in the dam which were provided on the right side of the river. At the beginning of March, 1915, all the work on the dam and in the high-water course was completed so that the water could be dammed up at any time.

The amount of concrete used in the dam alone was about 102,000 cu. m. and the average cost of this ranged from £1 5s. 6d. to £1 6s. 8d. per cu. m., while the work, with the exception of a small portion, was executed in a period of three years, 1912-15.

As previously mentioned, the rock used was blasted in the high-water course. The sand was obtained from the Brodremola gravel deposits in the neighbourhood of the Aysen railway station, situate about 17 kilometres south of Askim. On one occasion, in the early stages of the work, humic acid was found to be in this sand owing to some mistakes having occurred at the source of supply, and in consequence all the concrete which had been laid, wherein the sand was used, was blasted out and new material employed.

Careful tests of the cement used were conducted as the work proceeded, these consisting of tensile tests daily with samples made in proportions of 1 : 2, 1 : 3 and neat cement. The samples were each marked with a number and the date, and after mixing they were kept in the air for 24 hours, after which they were placed in water or moist sawdust until the test took place, the periods allowed being 4, 7, 14 and 24 days. In addition, samples were sent every week to the Material Testing Institute at Christiania, these samples being similar to the above, and, in addition, cubes 10 by 10 or 20 by 20 were sent for compression tests.

In the execution of the work great care was taken in cleaning the rock

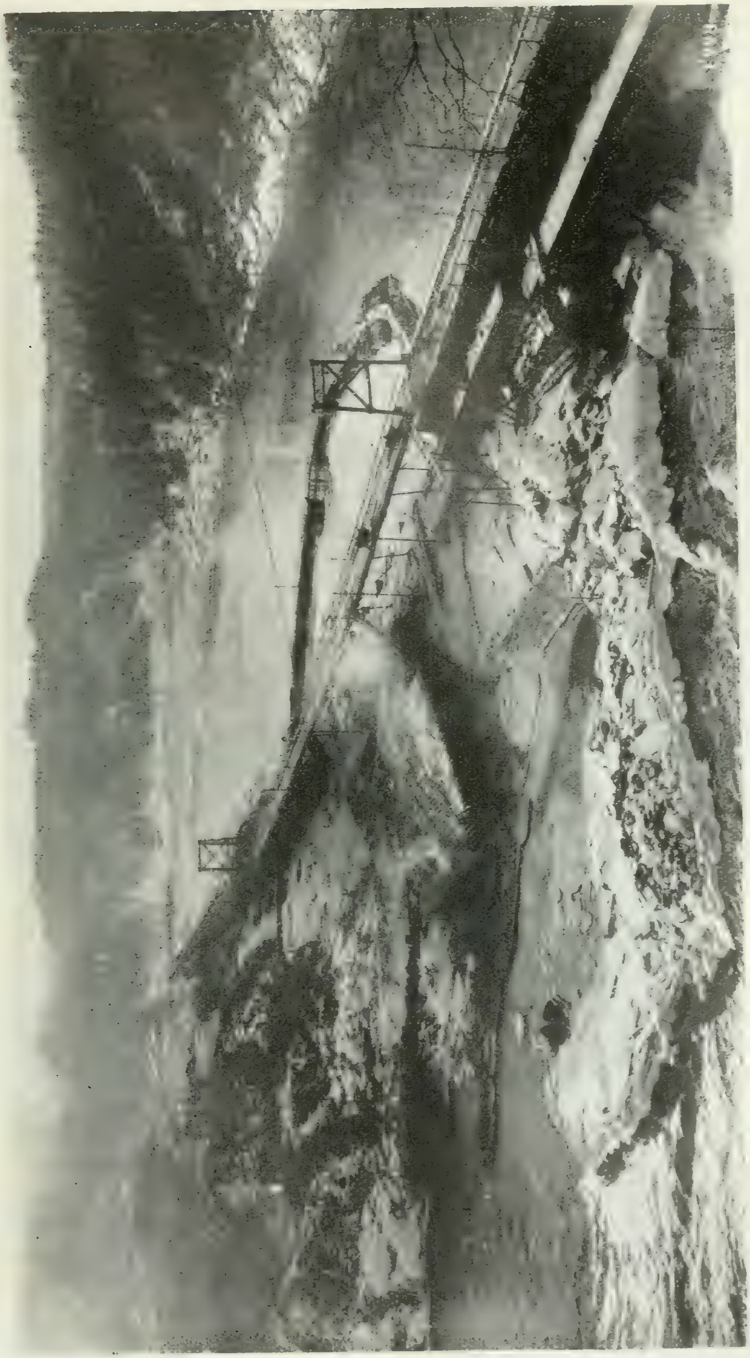


Fig. 3. View showing Progress of Work.
Concrete Work at the Vamma Power Station, Norway.

which formed the foundation of the dam at the bottom, and before any concrete was laid this rock was covered with a layer of rich mixture 1 : 3, 30 cent. thick.

During the early portions of the work the concrete was mixed in the proportions of 1 : 5 : 7 and the insertion of large stones was adopted to a considerable extent, these stones being as large as the transport arrangements would permit. The surface of the concrete next the water was covered with a layer 1 m. thick of rich mixture 1 : 3.

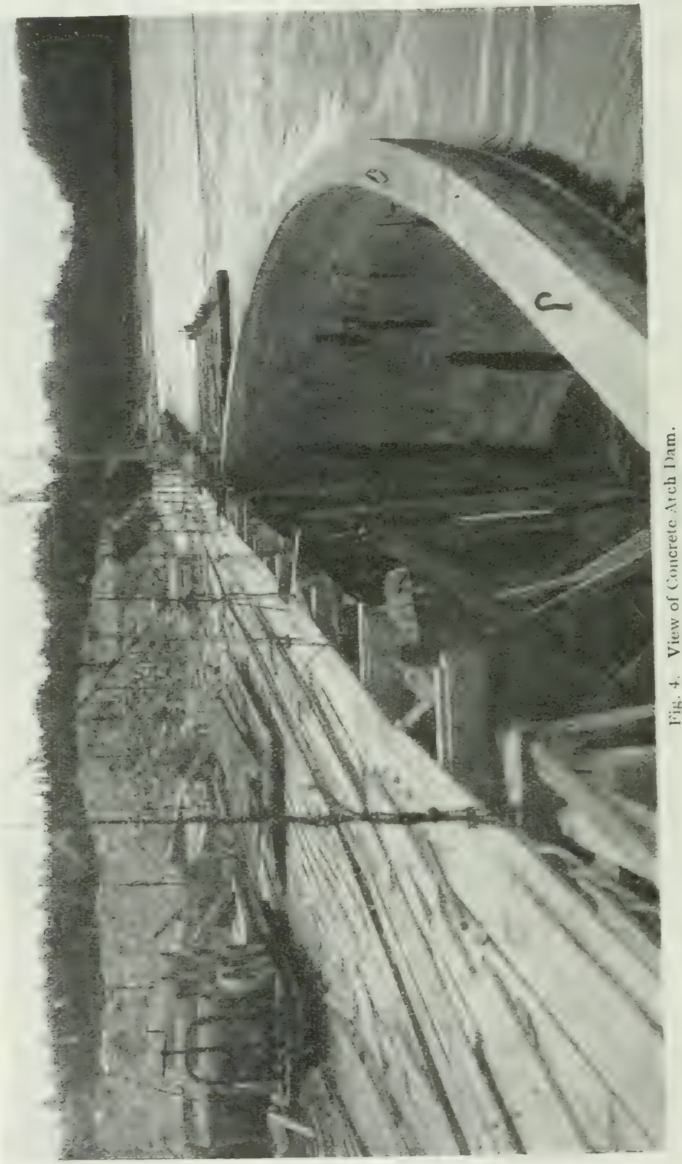


Fig. 4. View of Concrete Arch Dam.

Concrete Work at the Vamma Power Station, Norway.

The amount of water used was only sufficient to produce an ordinary earth-moist mixture. These original methods were entirely altered by degrees as the work proceeded and cannot be said to have had any influence upon the dam construction as a whole. From the year 1911 a richer concrete was used, the proportions being 1 : 4 : 6, and from that time the percentage of inserted stone was reduced and smaller stones were adopted. The greater part of the work done with the poor mixture was afterwards, for several reasons, blasted away, the removal being partly occasioned by the presence of humic acid in the sand, as previously mentioned. Other portions that proved to be porous on account of the weak mixture were grouted up with cement. This was accomplished by boring holes about 3 m. deep and about 1 in. diameter in the concrete, and in these holes pipes were inserted with funnels, two stop valves and a coupling piece for hose attached. The cement was mixed with water and then filled into the pipe, the upper valve was closed, and pressure by compressed air was brought to bear upon the material through the opening of the lower valve. This method proved very effective, and in some of the bore holes as much as forty or fifty bags of cement were forced in by repeated filling of the pipe. This grouting had the effect of increasing the strength of the concrete and rendering it equal to a 1 : 4 : 6 mixture.

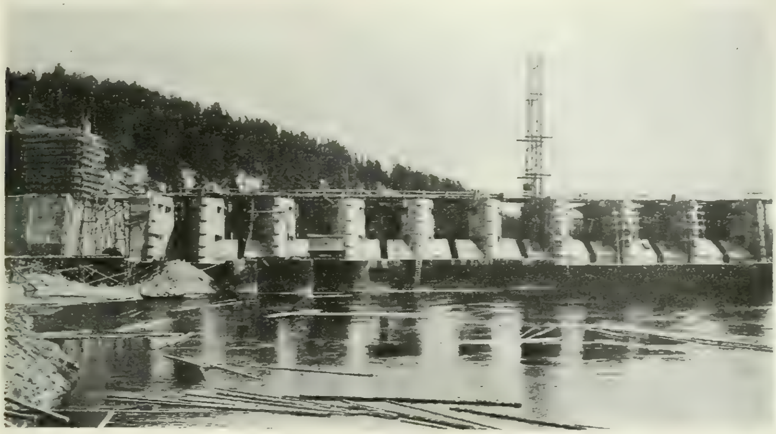


Fig. 5. Works in course of construction.
CONCRETE WORK AT THE VAMMA POWER STATION, NORWAY.

In those portions of the dam where the greatest stresses are likely to occur the concrete was mixed in the proportion of 1 : 3 : 5 and the insertion of stone was abolished. In addition to the rich mixture which was used on the water side of the dam a finishing coat of 1 : 2 mixture was also applied, and this in turn was painted with special waterproofing washes.

In order to provide expansion joints in the dam vertical grooves going right through the thickness were introduced at average distances apart of about 10 m. Great care was taken to make these joints so tight that water would not percolate, and to accomplish this a triangular cavity was made in the groove on the water side and the inside angle of this cavity was closed by means of a half pipe, after which the cavity was closed with concrete, reinforced in such a way that the wedge-shaped portion was connected with the mass concrete. Inside the wedge-shaped piece a pipe was further placed in the following manner. When the casting was being done a semicircular piece of wood was attached to one mould, and when the mould was removed this piece of wood was withdrawn, leaving a groove in the concrete. When the next portion was cast against this a semi-pipe was placed opposite the groove and the aperture thus formed was afterwards filled in with a mixture of gandron and inertol in weight proportion of 2 : 1.

Horizontally the concrete was laid in layers of 15 to 20 centimetres thick, and well tamped, and if circumstances caused a somewhat lengthy interruption of the concreting the horizontal grooves were "stepped" and laid as much as possible at right angles to the line of pressure.

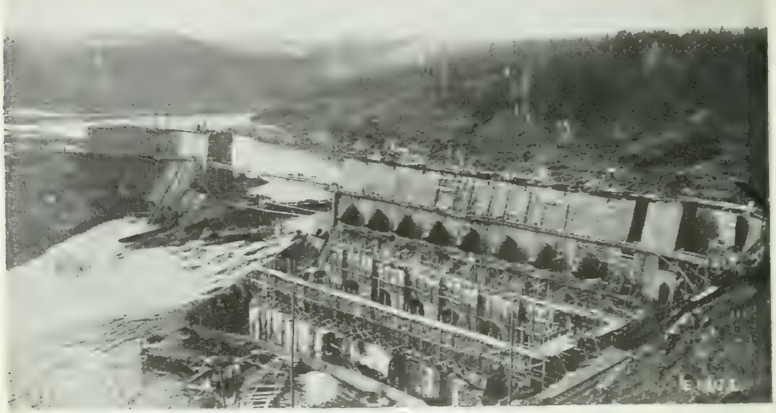


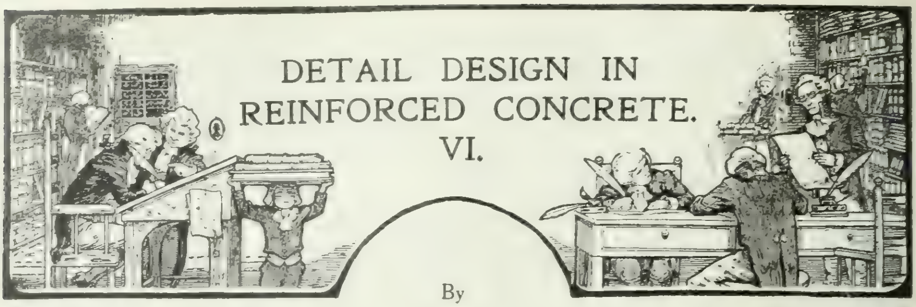
Fig. 6. Inlets to Power House.
CONCRETE WORK AT THE VAMMA POWER STATION, NORWAY.

When concreting was resumed after such delay the old concrete was carefully cleaned off, well washed down and covered with a layer of 1 : 3 mixture. During dry and warm weather the concrete that had recently been laid was well watered to prevent the drying out from being too rapid. Special precautions were taken when the temperature fell below six centigrades of frost, and heated materials were used when mixing the concrete. The heating of these materials was accomplished by means of perforated steam pipes which were placed in spirals along the sides of the storage silos and warm water was used in the mixing. To prevent the concrete freezing on the outer faces when it had been deposited the moulds were covered in with a special cloth and below this cover the necessary heating was brought about by means of coke pans. To control the temperature in the interior of the large casting moulds pipes were inserted in some places into which thermometers could be lowered, and these often registered quite high temperatures, reaching as much as 40 to 45 centigrades.

The dam was faced on the down stream side with granite, this being adopted for the sake of appearance and as a protection.

A carefully designed system of drainage was constructed to carry away any water that might percolate into the dam from the water side or from the bottom, this consisting of a series of 3-in. pipes on the entire water side at distances of 75 cent. and situated at a similar distance from the outer surface of the concrete. These are connected to collecting and emptying pipes of varying diameters up to 12 in. which discharge the water on the down stream side. Compressed air tools were tried as an experiment in the year 1912, and these proved so satisfactory that compressed air working was adopted for all boring, chiselling and tamping, and a compressed air plant was installed on either side of the river for this purpose.

The power station, transformer house and other auxiliary buildings were built entirely of concrete with reinforced concrete roofs. The lower part of the power house is below the water level, and this had to be built with special care with a view to its being watertight. This section was accordingly built with a very rich concrete, and, although this has not been rendered, the results have proved perfectly satisfactory, as the structure is quite watertight.



DETAIL DESIGN IN REINFORCED CONCRETE.

VI.

By

EWART S. ANDREWS, B Sc.Eng., M.C.I.

The last article of this series appeared in our issue of January, 1918.—ED.

DESIGN OF RETAINING WALLS.

General Considerations.—In designing a retaining wall to resist earth pressure, we have first to determine the resultant pressure of the earth upon the wall ; there are a number of different theories of earth pressure, the detailed consideration of which is beyond the scope of the present articles. For the present we will assume that the reader is familiar with these theories, and that the resultant pressure due to the earth is P_E, *Fig.* 21. The design of the wall may be considered under three heads :

1. Pressure upon the base.
2. Resistance to sliding of base.
3. Stresses in wall itself.

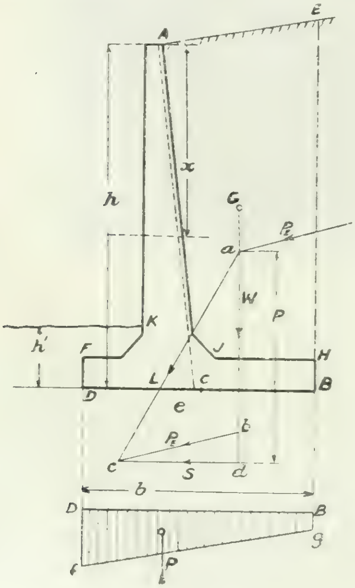


FIG. 21.

Pressure upon the Base.—Draw a vertical through the back B of the base slab, and let the resultant pressure per foot length of the wall, acting along the surface BE, be P_E. Next find the centre of gravity G of the weight of the wall and the earth in the portion $AJHE$; this can be done conveniently by taking moments about the point D. If W is the combined weight acting through G, the line of pressure ac is obtained by setting out from the intersection a of P_E and W a vertical length ab to represent W to a convenient scale, and a length bc parallel to P_E to represent it to the same scale. The intersection of the line of pressure ac with the base gives the load point L, and the distance e of this point from the centre C of the base gives the *eccentricity* of the load. The vertical component P of the thrust on the ground must be resisted by the upward reaction P of the ground, acting through the centroid of the pressure-distribution diagram. We now have two cases to consider.

1. *Load Point within Middle-third.* $\left(i.e., e \ngtr \frac{b}{6}\right)$.—In this case the pressure-distribution diagram is as shown by $DfgB$, and the maximum pressure Df must not be greater than the safe pressure upon the soil under consideration.

2. *Load Point Outside Middle-third* $\left(i.e., e > \frac{b}{6}\right)$.—In this case the pressure-distribution diagram is a triangle DhN, *Fig.* 22, DN being equal to $3DL$. Since the area of this diagram must represent the total pressure P, we have :

$$p \times \frac{DN}{2} = P$$

$$i.e.,\ p \times 3DL = 2P$$

$$\text{or } p = \frac{2P}{3\left(\frac{b}{2} - e\right)}$$

The value of the earth pressure P_E may be taken from the standard theories of earth pressure. Since these theories are necessarily incomplete, it is a good plan in practice to consider soils as having angles of repose of 30° or 45°, and to determine the earth pressure by means of the diagram shown in *Fig.* 23. φ may be taken as 30° for all soils except moist vegetable earth ; consolidated dry loam or vegetable earth ; damp, well-drained clay ; and clean gravel, for which φ may be taken as 45°.

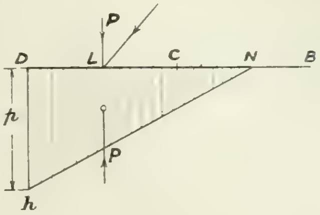


FIG. 22.

The following figures are commonly quoted for various kinds of earth :—

Material.	Weight per cu. ft. Lb.	Angle of Repose. φ degrees.
Sand, loose dry	100	31
,, consolidated dry	120	35
,, wet	115	32
,, very wet	120	26
Vegetable earth, dry	90	29
,, ,, moist	100	45–49
,, ,, very wet	105	17
,, ,, consolidated dry	100	49
Clay, with gravel	130	38
,, dry	110	29
,, damp, well drained	115	45
,, saturated	120	15
Gravel, clean	112	48
,, with sand	120	26
Loose shingle	115	29

Resistance to Sliding of Base.—The resistance of the base to sliding must be greater than the horizontal or slide component S of the forces on the base.

If φ^1 is the angle of friction between concrete and the earth, this resistance will be $W \tan \varphi^1$. In addition to this we may add the resistance to horizontal movement of the portion DFK of the wall, when the base of the wall is below the soil level on the unloaded side. This is sometimes called the " passive " resistance of the earth, and may be taken per foot length of the wall as

$$R_p = \frac{w_e (h^1)^2}{2} \left(\frac{1 + \sin \varphi}{1 - \sin \varphi} \right)$$

where w_e = weight of earth per cubic foot.

h^1 = depth of earth in feet.

φ = angle of repose of soil.

Stresses in Wall Itself.—The stresses in the wall and the corresponding design of the reinforcement depend on whether the wall is of the *cantilever type* shown in *Fig.* 21 or of the *counterforted type* which we will consider later. In the cantilever type we have first to design the wall slab portion proper as a cantilever subjected to the bending moments caused by the earth pressure ; the direct compression stress due to the weight of the wall slab itself will be so small that we may neglect it for practical purposes. We next have to design the slab portion *JH* as a cantilever subjected to bending moments and shear forces due to the difference to the weight of filling above and the upward pressure from the earth below ; and, finally, have to design the portion

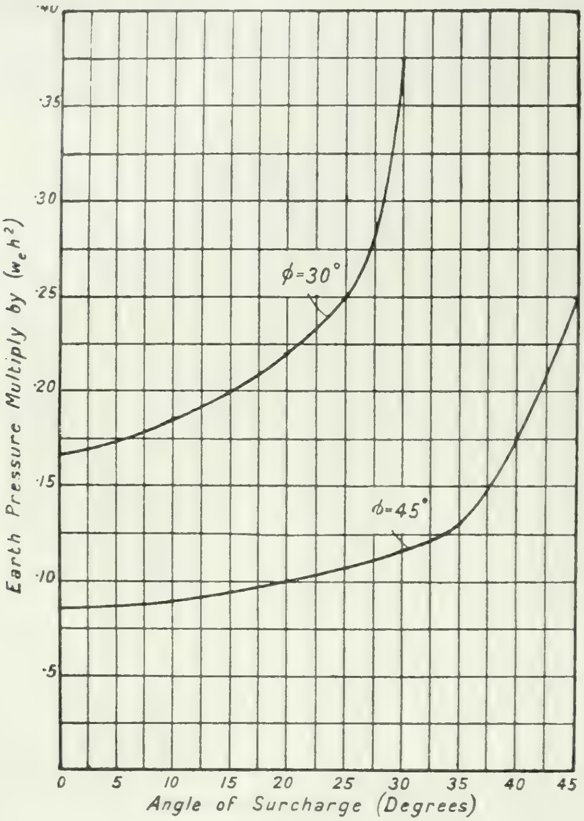


Fig. 23.

FK as a cantilever to carry the bending moment and shear from the earth below, the weight of filling above being negligible. The necessary calculations will be made clear from a study of the following numerical example.

Numerical Example of the Design of a Cantilever Wall.—Take the case of the wall illustrated in *Fig.* 24, the height of wall being 16 ft. from the bottom of the slab, and the earth being horizontal at the back of the wall.

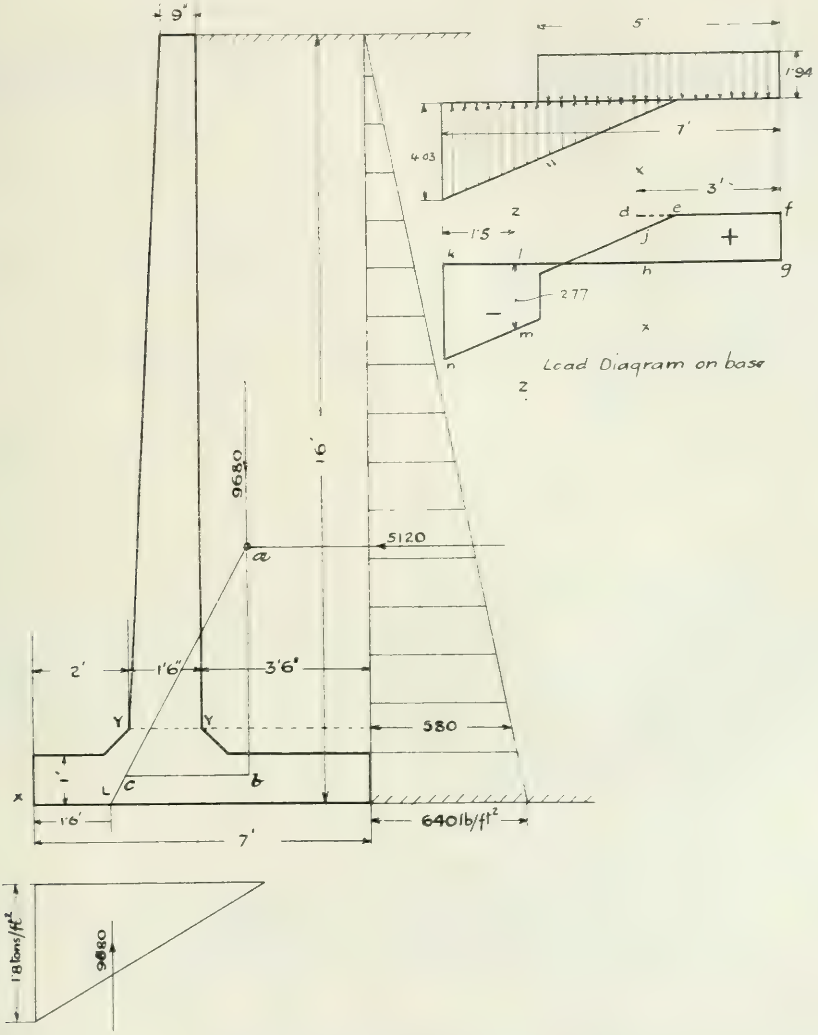


FIG. 24.

We will take the following figures :—

Weight of earth $= w_e = 120$ lb. per cu. ft.

Angle of repose $= \varphi = 30°$.

We will consider as is usual one foot length of wall at right angles to the plane of the paper.

From *Fig.* 23 we find $P_E = 0{\cdot}167 \times w_e h^2$

$$= 0{\cdot}167 \times 120 \times 256$$
$$= 5{,}120 \text{ lb.}$$

The total weight of wall and filling $= W = 9{,}680$ lb.

The total moment about the point X of the weight of wall and filling comes equal to 43,400 lb. ft.

$\therefore$ distance of resultant weight from $X = \frac{43{,}400}{9{,}680} = 4{\cdot}48$ ft.

On drawing the force triangle in the manner previously explained, we find that the load point L comes at a distance 1·6 ft. from the edge L. This comes outside the middle-third, so that the diagram of pressure distribution will be as shown in *Fig.* 22.

$\therefore$ maximum pressure on foundations $= \frac{9{,}680 \times 2}{3 \times 1{\cdot}6}$

$$= 4{,}030 \text{ lb. per sq. ft.}$$
$$= 1{\cdot}8 \text{ tons per sq. ft.}$$

We will assume that the soil is of confined sand, and that therefore in accordance with regulation **136** the allowable pressure is 2 tons per sq. ft. Our design is therefore satisfactory from the standpoint of pressure upon the soil.

Considering next the question of sliding of base, we have, if we take $\tan \varphi^1 = 0{\cdot}5$ for concrete on confined sand,

$$W \tan \varphi^1 = 0{\cdot}5 \times 9{,}680 = 4{,}840 \text{ lb. per sq. ft. length.}$$

We will take h^1, *Fig.* 21, equal to 2 ft., so that the passive resistance of earth at front of wall per foot length,

$$R_p = \frac{w_e (h^1)^2}{2} \cdot \frac{(1+\sin \varphi)}{(1-\sin \varphi)} = \frac{120 \times 2^2 \times 1{\cdot}5}{2 \times 0{\cdot}5}$$
$$= 720 \text{ lb.}$$

$\therefore$ Total resistance to sliding $= 4{,}840 + 720 = 5{,}560$ lb.

The maximum possible horizontal force tending to cause sliding has been shown to be equal to $P_E = 5{,}120$ lb., so that our wall is stable from this point of view.

Reinforcement Required in Wall.—Taking first the vertical wall slab, we notice that it is a vertical cantilever subjected to a horizontal force of uniformly increasing intensity. The section of greatest stress will be YY, for which x, *Fig.* 21, is 14·4 ft. approximately, and the corresponding intensity of pressure is 580 lb. per sq. ft.

$\therefore$ Max. B.M. $= B = \frac{14{\cdot}4 \times 580}{2} \times \frac{14{\cdot}4}{3} = 20{,}100$ lb. ft.

$$= 241{,}000 \text{ lb.-in.}$$

The effective depth d may be taken as 16 in.

$$\therefore \frac{B}{bd^2} = \frac{241{,}000}{12 \times 16 \times 16} = 78{\cdot}5 \text{ approx.}$$

$\therefore$ From *Fig.* 3, reinforcement required $= 0{\cdot}56$ per cent.

$\therefore$ Area of reinforcement per inch width $= \frac{0{\cdot}56 \times 16}{100} = 0{\cdot}09$ approx.

The area of a $\frac{7}{8}$-in. bar is 0·601 in., so that we may take $\frac{7}{8}$-in. bars at 6 in. apart, alternate bars being long and short, as shown in *Fig.* 25, on account of the diminution of bending moment towards the top.

It will be noted that regulation **28** states the length of a cantilever shall not exceed five times the effective depth at the bearing, and that we have not complied with this; in our opinion this regulation cannot be intended to apply to vertical slabs of retaining walls, as insistence upon its use would render economic design impossible.

It is a severe regulation even for cantilevers proper occurring as part of a building frame.

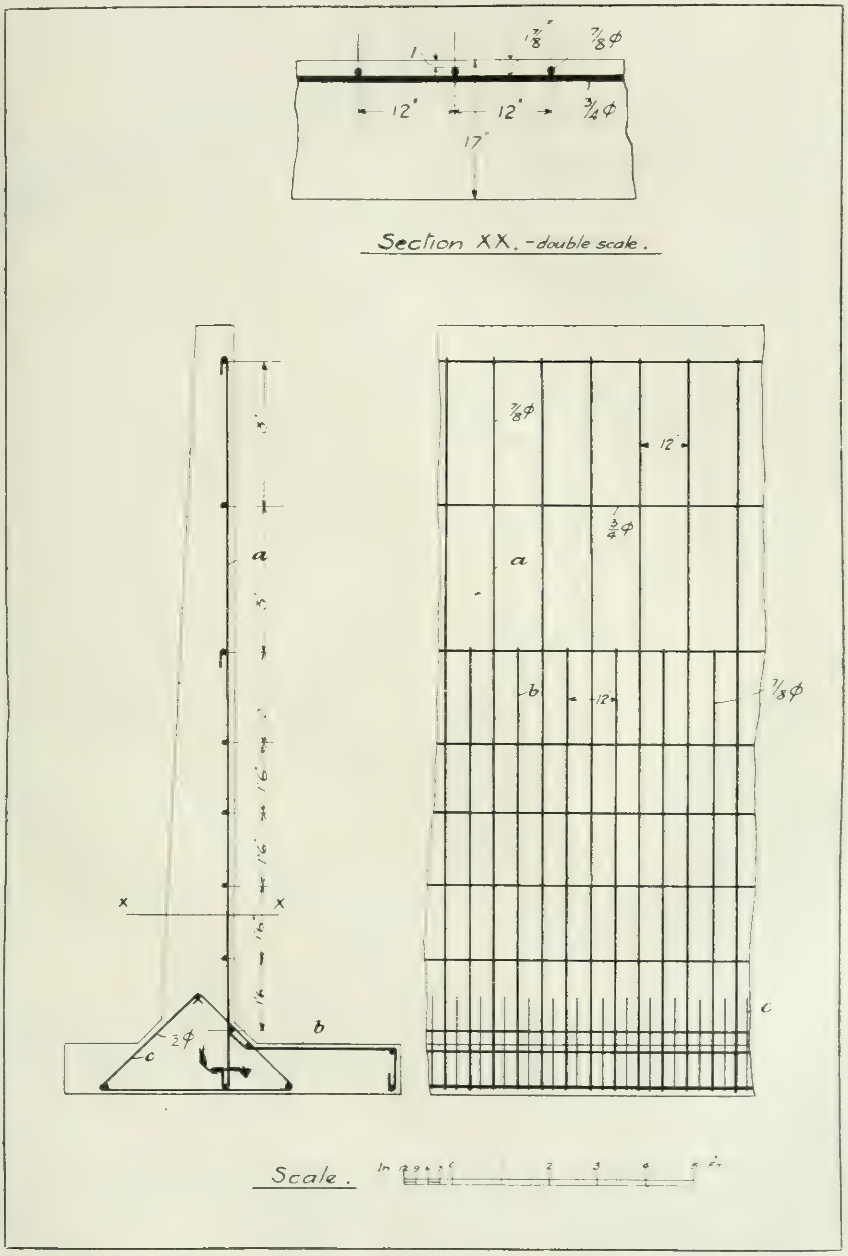


FIG. 25

Distribution bars will be provided in accordance with regulation **78** at a maximum pitch of 18 in. or four times the effective depth of the slab ; the area is to be at least

0·08 per cent. of the effective cross-sectional area of the slab or the diameter at least $\frac{1}{16}$ of the effective depth.

Taking the first condition with a pitch of 18 in., we shall require an area of $\frac{0{\cdot}08\times 18\times 16}{100}=0{\cdot}23$ sq. in., corresponding to a bar diameter of not less than $\frac{5}{8}$ in.; the second condition would require 1-in. bars at distances not greater than 5 ft. 4 in. This great divergence in results is, of course, due to the large effective depth of the slab.

We will adopt $\frac{3}{4}$-in. bars at 18 in. apart at the bottom, increasing to 3 ft. apart towards the top as shown, where the effective depth is less.

To calculate the reinforcement required in the bottom slab, we have first to obtain the load diagram. The load upon this consists, as shown at the left-hand side of *Fig.* 24, of an upward pressure, distributed in the form of a triangle as we have already shown, and the downward pressure due to the weight of the wall and filling, which we may take as distributed in the form of a rectangle as shown; the downward pressure over the left-hand projecting portion is sufficiently small to be neglected in our calculations. The difference between the triangle and the rectangle gives the load diagram for which the base slab should be designed.

The critical section for the right-hand slab is XX, and to find the bending moment at this section we have to take the moment about XX of the rectangle *dfgh*, and subtract the moment of the triangle *dej*. In one particular example the latter moment will be of negligible value, but this will not be so in all cases arising in practice.

∴ Considering a foot width of slab, we have

$$B_X=\left(1{\cdot}94\times 3\times \frac{3}{2}\right)\ 12\ \text{kip-in.}$$
$$=87{\cdot}3\ \text{kip-in.}$$

Taking $d=10{\cdot}5$, we have $\frac{B}{db^2}=\frac{87{\cdot}3\times 1{,}000}{12\times 10{\cdot}5\times 10{\cdot}5}=66$ approx.

∴ From diagram of *Fig.* 3, per cent. reinforcement required $=0{\cdot}47$.

∴ Reinforcement required per inch width $=\frac{{\cdot}47\times 10{\cdot}5}{100}={\cdot}49$ sq. in. approx.

$\frac{7}{8}$-in. bars 12 in. apart will be sufficient, so we will bend round the shorter vertical bars as shown in *Fig.* 25; this reinforcement is, of course, required at the top of the slab. Regulation **77** prevents us from spacing these bars farther apart.

For the slab on the left-hand side the principal question to be considered is the shear at the section ZZ.

The shearing force at this section = area *klmn*

$$=\left(\frac{4{\cdot}03+2{\cdot}77}{2}\right)\times 1{\cdot}5=5{\cdot}1\ \text{kips.}$$

$0{\cdot}18bd=0{\cdot}18\times 12\times 10{\cdot}5=22{\cdot}7$ kips, so that regulation **66** is satisfied. Moreover, this calculation shows that the shearing stress which we may take as $\frac{5{\cdot}1\times 1{,}000}{12\times 9}=47$ lb. per sq. in. approx., is less than is allowed by the regulations without special shear reinforcement.

Nevertheless, we regard it as desirable to provide some shear reinforcement, and we therefore adopt $\frac{1}{2}$-in. bars at 12-in. centres, bent up as shown in *Fig.* 25.

The shear on the section $XX=3\times 1{\cdot}94=5{\cdot}82$ kips; this will cause a stress which is still within the allowed limits, but the section is further strengthened by the $\frac{1}{2}$-in. bars provided.

(*To be continued.*)

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SOME RESULTS OBTAINED BY PROPORTIONING WATER IN CONCRETE TESTS.

Ratio of Water to Cement Found to have more Important Effect on Strength than Quantity of Cement or Grading of Aggregates.

By DUFF A. ABRAMS,

Professor in Charge of Structural Materials Research Laboratory, Lewis Institute, Chicago.

The following article, reproduced from "Engineering News Record," gives the results of some important Tests made by Prof. Abrams at The Structural Materials Laboratory of the Lewis Institute, U.S.A., regarding the proportioning of concrete.—ED.

CONCRETE, it is commonly stated, is composed of a mixture of cement, sand and pebbles or crushed stone. This conception of concrete overlooks one essential element of the mixture—water. An exact statement of the ingredients of concrete would be: Cement, aggregate, and water. The last-named material has not yet received proper consideration in tests of concrete or in specifications for concrete work.

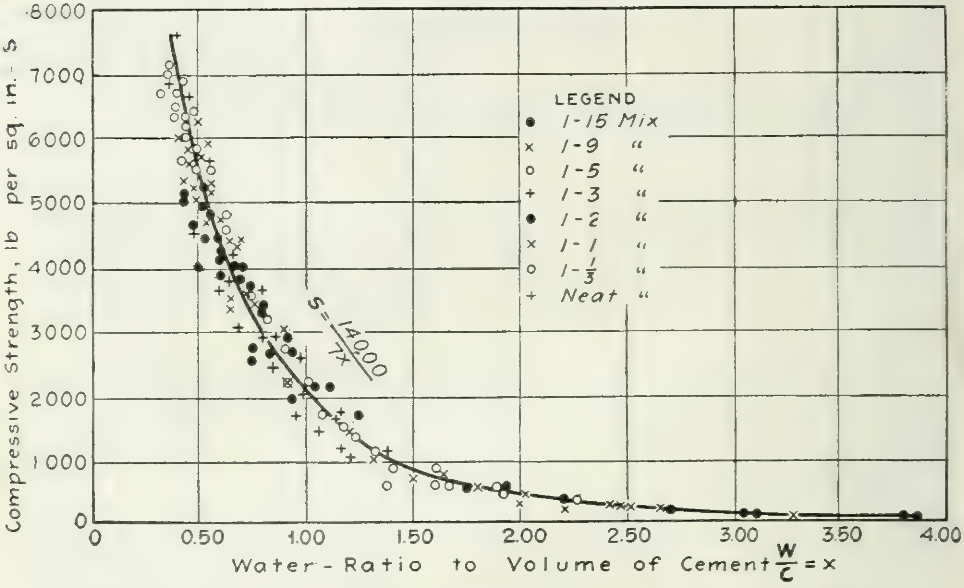
Early users of concrete centred their entire attention on the quality of the cement, and practically disregarded the characteristics of the other ingredients. During the past dozen years some attention has been given to the importance of the aggregate, but it is only recently that we have learned that the water also requires consideration.

A great deal has been said and written recently concerning the effect of water on the strength and other properties of concrete, but the full significance of this ingredient has not heretofore been pointed out. A discussion which appeared in the April, 1917, issue of the *Concrete Highway Magazine* gave a brief review of results of some of the experimental work carried out along this line at the Structural Materials Research Laboratory, Lewis Institute, Chicago. The relation between the water content and the compressive strength of the concrete for a wide range of consistencies was there pointed out and emphasis was placed on the injurious effect of too much water. Tests made in studies of the effect of size and grading of aggregates have shown that the only reason concrete of higher strength and durability can be produced from well-graded aggregate as compared with a poorly-graded aggregate is that the former can be mixed with less water. If this is not done no advantage is gained from using a coarse, well-graded aggregate. The following discussion shows that a similar conclusion can now be stated with reference to a rich concrete mix as compared with a lean one.

While the injurious effects of too much water in concrete is apparent, tests made in this laboratory show that the truly fundamental rôle played by water in concrete mixtures has been entirely overlooked in previous discussions of the subject. The relation referred to above is brought out by a series of compression tests of about 1,600 6×12 in. concrete cylinders made up as follows:

Mix Cement-Aggregate.	Range of Sizes of Aggregates.	Consistency.
1 : 15		
1 : 9	0–14 mesh sieve	
1 : 5	0–4 mesh sieve	Different consistencies for each mix and aggregate.
1 : 3	0–¾-in.	
1 : 2	0–1½-in.	
1 : 1	0–2-in.	
1 : ⅓		
Neat		

The mixes used covered a wide range, as did also the grading of aggregate and consistency. The aggregates consisted of two sizes of sand and mixtures of sand and pebbles graded to the sizes shown. The mix is expressed in terms of volumes of dry cement and aggregate, regardless of grading—*i.e.*, a 1 : 5 mix is made up of 1 cu. ft. cement (1 sack) and 5 cu. ft. of aggregate as used, whether a sand or a coarse concrete mixture.



LEAN AND RICH MIXTURES SHOW STRIKING SIMILARITY IN STRENGTH VARIATION FOR DIFFERING WATER CONTENTS

This series gives valuable information on the effect of changing the quantity of cement, the size of the aggregate, and the quantity of water. The effect of many different combinations of these variables can be studied. One set of relations gives the effect of amount of cement using aggregates of different size and grading; another set of relations gives the effect of different quantities of water, varying both mix and size of aggregate. In all respects the tests bear out the indications of earlier and later series, and reveal the true relation between the strength and the proportions of the constituent materials in concrete. The figure shows the relation between the compressive strength and the water content for the twenty-eight-day tests. The water content of the concrete has been expressed as a ratio of the volume of cement, considering that the cement weighs 94 lb. per cu. ft. Distinguishing marks are used for each mix, but no distinction is made between aggregates of different size or different consistencies.

When the compressive strength is platted against the water in this way a smooth curve is obtained, due to the overlapping of the points for different mixes. Values from dry concretes have been omitted. If these were used we should obtain a series of curves dropping downward and to the left from the curve shown. It is seen at once that the size and grading of the aggregate and the quantity of cement are no longer of any importance except in so far as these factors influence the quantity of water required to produce a workable mix. This gives us an entirely new conception of the function of the constituent materials entering into a concrete mix and is the most basic principle which has been discovered in our studies of concrete.

The equation of the curve is of the form :

$$S = A/B^x \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where S is the compressive strength of concrete and x is the ratio of the volume of water to the volume of cement in the batch, A and B are constants whose values depend on the quality of the cement used, the age of the concrete, and curing conditions.

This equation expresses the law of strength of concrete so far as the proportions of materials are concerned. It is seen that for given concrete materials the strength depends on one factor only—the ratio of water to cement. Equations which have been proposed for this purpose contain terms which take into account such factors as quantity of cement, proportions of fine and coarse aggregate, voids in aggregate ; but they have uniformly omitted the only item which is of any importance, the water.

The relation given above holds so long as the concrete is not too dry for maximum strength and the aggregate not too coarse for a given quantity of cement ; in other words, so long as we have a workable mix.

For the conditions of these tests equation (1) becomes :

$$S = 14{,}000 \ 7^x \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Other tests made in this laboratory have shown that the character of the aggregate makes little difference if it is clean and not structurally deficient. The absorption of the aggregate must be taken into account if comparison is being made of different aggregates.

In certain instances a 1 : 9 mix is as strong as a 1 : 2 mix, depending only on the water content. The strength of the concrete responds to changes in water, regardless of the reason for these changes.

It should not be concluded that these tests indicate that lean mixes can be substituted for richer ones without limit. We are always limited by the necessity of using sufficient water to secure a workable mix. So in the case of the grading of aggregates. The workability of the mix will in all cases dictate the minimum quantity of water that can be used. The importance of the workability factor in concrete is, therefore, brought out in its true relation.

The reason a rich mix gives higher strength than a lean one is that a workable concrete can be produced by a quantity of water which gives a lower ratio of water to cement. If an excess of water is used we are simply wasting cement. Rich mixes and coarse, well-graded aggregates are necessary as ever, but we now know just how these factors affect the strength of the concrete.

Practical use may be made of the curve in estimating the relative strength of concretes in which the water content is different for any reason. For example, a concrete mixed with 7·5 gallons of water (1 cu. ft.) to one sack of cement (allowance being made for absorption of aggregate) gave a strength in this series of 2,100 lb. per sq. in. ($x=1·00$). For $x=0·80$ (6 gal. of water per sack of cement) we have 3,000 lb. per sq. in.; for $x=0·75$ (5·6 gal.) 3,300 lb. per sq. in. Concrete in a 1 : 4 mix (same as usual, 1 : 2 : 3 mix with a coarse sand) should be mixed with 5½ to 6 gal. of water per sack of cement.

The importance of any method of mixing, handling, placing, and finishing concrete which will enable the work to be done with a minimum of water is at once apparent. It now seems that practically all faulty concrete work can be traced to the use of too much water.

These studies lead to many important conclusions with reference to such topics as tests of cement, tests of concrete containing admixtures, etc. Tests of cement from this viewpoint have been under way several weeks.

NOTES ON BUILDING CONCRETE VESSELS.

For the following abstract of an article by Prof. E. Suenson, of Copenhagen, in "Beton u Eisen," we are indebted to A. B. Searle.—ED.

POROUS concrete is readily attacked by sea water, so that in the construction of ships it is necessary to use a dense concrete. Further protection may be afforded by coating the exterior with tar or asphalt. The objection to tar is the ease with which limpets, barnacles, etc., adhere to it. (Possibly this might be overcome by supplying a coating of cement or gravel on the surface of the tar.)

Concrete vessels may be constructed either (*a*) on an inside mould or core covered with the reinforcement, and the concrete is then applied until the latter is suitably embedded, or (*b*) the concrete may be poured between two shutterings which form the mould. On the whole, the second method gives the better results, especially if the concrete is well tamped so as to remove all air and excess of water present and to form a solid and dense mass. Such a texture cannot be obtained by throwing the concrete on to a core, as in such a case any air present remains in the concrete and the excess of water does not float to the surface of the mass.

In order to render the concrete waterproof a water repellant must be added to it during the mixing, or the surface must be smoothed and a waterproof coating applied.

The walls of concrete vessels are usually so thin that the ordinary calculations of their bending moments do not apply. A thickness of 2½ in. seems to be quite serviceable, even in the largest vessels, but smaller craft must be made much thinner on account of the weight of the vessel. The minimum satisfactory thickness should not depend on any calculation as to the blows likely to be received by the vessel so much as on the quality of the concrete and the possibility of introducing it into the mould.

Where the moulding can be satisfactorily effected a thickness of ½ in. has been proved to be sufficient.

The use of supporting irons fixed at an angle of 45 degrees to the horizontal and arranged in pairs at right angles to each other has the advantage of resisting oblique tension during the sideways movement of the vessel better than the reinforcement usually adopted.

A double bottom is seldom required, and it adds unnecessarily to the weight of the vessel as well as preventing an investigation of the state of the concrete in the lower portion.

The Danish shipbuilders have a rule that the bottom of concrete vessels must resist a water pressure equal to that of the greatest depth of immersion plus 1-40th of the length of the vessel. In Norway it is customary to make the bottom strong enough to resist the water pressure at twice the maximum depth of immersion.

Concrete decks should be able to carry a load of 170 lb. per sq. ft.

Severe tensional strains are very objectionable in concrete vessels, as they tend to form cracks which admit water to the reinforcement and cause it to rust. At present there is no reliable basis of calculation to determine the conditions under which such cracks would be formed in the largest vessels. In smaller ones the problem does not appear to be serious.

The tensile strength and shearing stresses permissible in the reinforcement are taken at 14,000-16,800 lb. per sq. in. and 11,200-440 lb. per sq. in. respectively; and for the concrete, maximum load is taken at 0·1-0·14 of the crushing strength, and the bending strain at 560 lb. per sq. cm.

It is not reasonable to insist that the strength of concrete shall be based on data which have been found satisfactory for steel vessels, as the latter are subject to rusting and other factors which have been taken into account when designing them, but which have no bearing on vessels made of concrete. Thus the longitudinal strength of a vessel is based on the assumption that its main trochoid has an axial height of $L \div 20$.

The crosswise strength of vessels is based on the assumption that the whole load may be stowed in only one half of the hold. The base, side walls, and deck are often designed without much regard for static considerations, as there are so many influences exerted on vessels when afloat which render rigid static calculations unnecessary.

In barges and other vessels without decks it is usually assumed that the bottom and sides form a double-linked framework with a horizontal shearing stress (H).

$$H = \frac{qb}{4h}\left(\frac{b}{3 + 2\frac{s}{b}} + 2a\right)$$

where q is the greatest outwards water pressure less the total load distributed over half the length of the vessel. The latter is taken in two separate cases: (1) where the load is placed uniformly in the centre of the vessel; (2) where the load is placed between the centre and end of the hold.

b is the width at the bottom of the vessel.

h is the height of the vessel.

a is half the difference between the width at top and bottom of the vessel.

s is the sloping height (measured along the side).

In the vessels with deck-supporting bearers it is assumed that the latter form a double linked frame with the sides. In this case :

$$H=\frac{pl}{4h}\left(\frac{l}{3+\frac{2s}{l}}-2a\right)$$

where p is the load or weight unit length of deck.
l is the width of the deck.
a is the difference between the greatest and smallest widths of the vessel.
s is the sloping height of the vessel.

Sea-going vessels more than 120 ft. in length require to be made much stronger (up to double the bending moments) than those for inland water.

PRODUCING DENSE CONCRETE.

(*Abstract of a paper by Dr. Vieser in "Eisen u Beton."*)

CONTRARY to the common opinion, a sand with grains of uniform size is *not* the best for concrete.

The most satisfactory sand consists of a mixture of coarse grains with sufficient finer ones to fill the interstices.

The determination of the percentage of voids in a dry-rammed aggregate without any cement is of no value.

The best mixture for general work consists of 53 per cent. of coarse sand with 1/12 in.-¼ in. diam., 47 per cent. of fine material with grains less than ⅙ in. diameter.

Grains of intermediate sizes are not satisfactory.

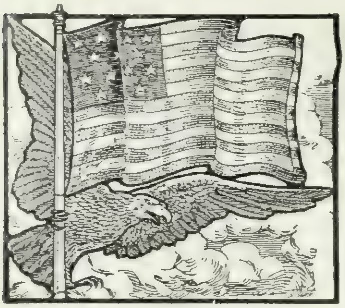
The finest grains of sand should be quite clean and free from clay. They should be ground with the dry cement previous to use.

There appears to be a definite percentage of cement above which it is useless to go, as the concrete is not improved. This maximum point is about 30 per cent. of the finished concrete, but varies with different aggregates.

Crushed stone is better than natural sand, as the grains are more angular and the sand sharper.

To secure the best results four ingredients are recommended :—

(*a*) Coarse aggregate, pebbles, gravel, etc.
(*b*) Coarse sand (1/12 in.-¼ in. diam.).
(*c*) Very fine sand (less than ⅙ in. diam.).
(*d*) Cement.



CONCRETE IN SEA WATER.

By R. J. WIG and L. R. FERGUSON.

III.

Continued from March issue. The question of the behaviour of concrete in sea water is one of the greatest importance, and the result of some most interesting and instructive examinations of such concrete structures has recently been published in "Engineering News Record," in the form of five articles, of which we reprint the third herewith. The investigations were carried out by Messrs. R. J. Wig (Bureau of Standards, U.S.A.) and L. R. Ferguson of the Portland Cement Association. The investigations extended over a period of two years, during which 146 different structures in the United States alone were examined. The authors, in the course of this article, state:—"It is not the intention to demonstrate that concrete cannot be used for marine structures. On the contrary it is their opinion that it is a most economical material, if it is made so as to successfully resist sea water action, and it is their opinion that it can be made so."—ED.

THE majority of all reinforced concrete marine structures on the American coasts subjected to sea-water action are now showing evidences of deterioration or failure due to the corrosion of the embedded reinforcement above the water line.

Only after the most careful investigation, and with indisputable evidence at hand to substantiate it, do the authors state *that steel embedded in first-class concrete to a depth of one or two inches in accordance with existing theory and practice is not perfectly protected against corrosion by sea-water action.* There is a widespread but erroneous belief among engineers that a comparatively thin coating of concrete will protect embedded reinforcing from corrosion. This view is supported by the leading authorities, and so the average engineer cannot be severely censured for following a practice which has the sanction of those whom he supposes to be well versed in the subject. For instance, the 1917 report of the Joint Committee on Concrete and Reinforced Concrete states:—"Tests and experience indicate that steel sufficiently embedded in good concrete is well protected against corrosion no matter

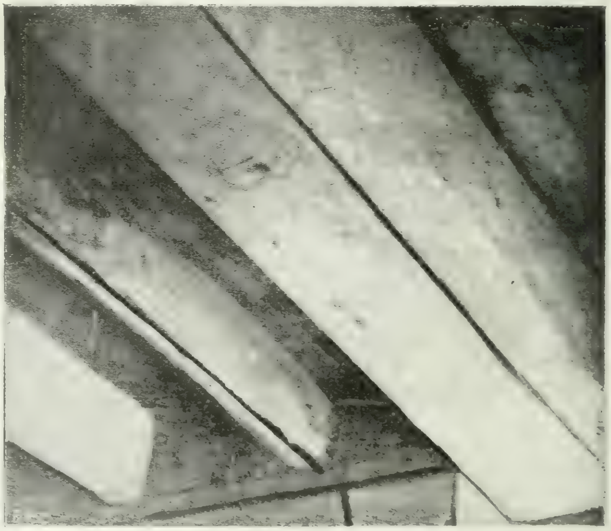


FIG. 14. CORROSION OF SLIGHTLY EMBEDDED STEEL CAUSED CRACKING WITHIN A YEAR.

whether located above or below water level. It is recommended that such protection be not less than 1 in. in thickness." This also represents the opinion of the authors of all standard works.

Some of the structures examined by the writers are not a year old, and the oldest is but ten. Many of the older structures show signs of advanced deterioration, and some not more than four years old are badly affected, while one reinforced concrete pleasure pier, opened to the public in July, 1916, was found to be seriously affected by October of the same year. Some of its members are shown in *Fig.* 14. In that short time the reinforcing had corroded to such an extent that spalling of the concrete had begun.

In many instances where a member has cracked over some of the rods the cracking has not yet developed over all of them—that is, one corner of a beam or pile may be cracked while the other corners show no signs of fracture. This is due to the fact that some of the rods are embedded a little deeper, the concrete is somewhat denser, or the exposure is not so severe.

A number of reinforced concrete structures were found which were not cracked or deteriorated, but most of these were not over two or three years old. One, however, was ten years old.

Undoubtedly the most important information gained during the recent investigation made by the authors was the true condition of reinforced concrete structures subjected to the action of sea water, and the cause of the trouble. There have been a number of reports and articles in the technical Press describing marine structures of reinforced concrete which have shown signs of deterioration, but as far as is known no one has developed the real conditions.

Some plausible explanation has always been made which has accorded with the existing theory that reinforcing is amply protected against corrosion when embedded to a depth of 1 or 2 in. in concrete of good quality. These articles have described structures in widely separated localities, so it is evident the same forces are at work wherever there is sea water, and the trouble is not confined to any particular part of the country. The effect, however, is much more pronounced in some localities than in others, and certain conditions greatly accelerate the action. The temperature, exposure conditions, quality of concrete, and depth of embedded metal all influence the rapidity of deterioration. Some of the reinforced concrete structures examined by the authors show only slight signs of deterioration after six or seven years of exposure, while others are practically failures within four years of the time they were built.

Usually the corrosion of reinforcing is attributed to the poor quality of the concrete. Porous concrete does, of course, offer less protection to the embedded metal, and corrosion will be more rapid in such cases. Reinforcing will, however, corrode under certain exposure conditions in a few years, even when the concrete is of excellent quality.

There is a reinforced concrete quay wall or wharf on the south Atlantic coast which was built in 1912 which illustrates this. The design consists of pre-cast reinforced concrete piles supporting a reinforced concrete deck. The concrete for the piles was a 1 : 1½ : 3 mix, so wet that the rods were thoroughly coated. The ingredients were of excellent quality, and the concrete was mixed and placed as well as if not better than the usual practice. *Fig.* 15 shows one of the cracked piles and a section of concrete showing its good quality. When this wharf was examined in 1916 it was found that 60 per cent. of the piles were cracked at the corners, and in many cases the reinforcing was exposed.

There is another pier along the Atlantic coast, built ten years ago, which consists of pre-cast concrete piles, but here a wood deck was used. The concrete for the piles was of good quality. In this pier there are about 2,500 piles, and nearly every one is cracked or spalled. *Fig.* 15 shows some of the piles.

In the Philippine Islands many of the reinforced structures have cracked to such an extent, due to the corrosion of the metal, that they have caused serious apprehension. The explanation advanced by J. L. Harrison, at one time district engineer at Iloilo, P. I., in an article in *Concrete*, March, 1917, is that the trouble is caused by the use of sea water in mixing the concrete.

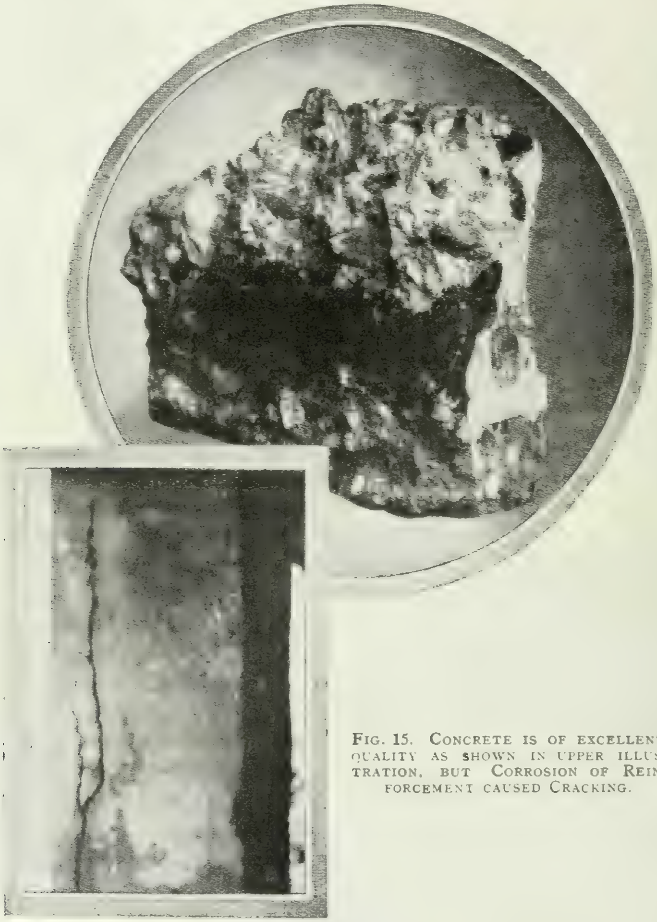


Fig. 15. Concrete is of excellent quality as shown in upper illustration, but Corrosion of Reinforcement caused Cracking.

Mr. Harrison came to this conclusion largely by analysing specimens of concrete which had cracked, and in these he found an appreciable amount of chlorine. He was on the right track, but the chlorine did not come necessarily from the salt in the water used in mixing the concrete, and, moreover, the conditions he observed would without doubt have occurred had the concrete been gauged with fresh water. He is also in error in assuming "that on the whole the conditions in the Philippine Islands are so different from those which prevail in temperate climates that the results there (in the United States) obtained are not a reasonable criterion of what must be expected here."

Exactly the same phenomena are occurring in America, and, in fact, everywhere that concrete is exposed to sea water. Under warm, humid conditions the action is much more severe and rapid; but more or less rapidly the destructive action is in progress everywhere.

SALT WATER GAUGING NOT THE CAUSE OF FAILURE.

That the gauging of the concrete with sea water or the use of aggregate impregnated with salt water is not the primary or underlying cause of the corrosion of the embedded reinforcing is shown by the fact that in many of the structures examined the concrete was mixed with fresh water and the aggregates were free from contact with salt water. This was true of the two piers first referred to where very extensive cracking has occurred. During the investigation made by the authors one of the matters given particular attention was the possible use of salt water in gauging the concrete, and the statement can be made with assurance that the prevailing corrosion of metal embedded in concrete cannot be attributed to the use of sea water in mixing, for with few exceptions American structures have been built with fresh water.

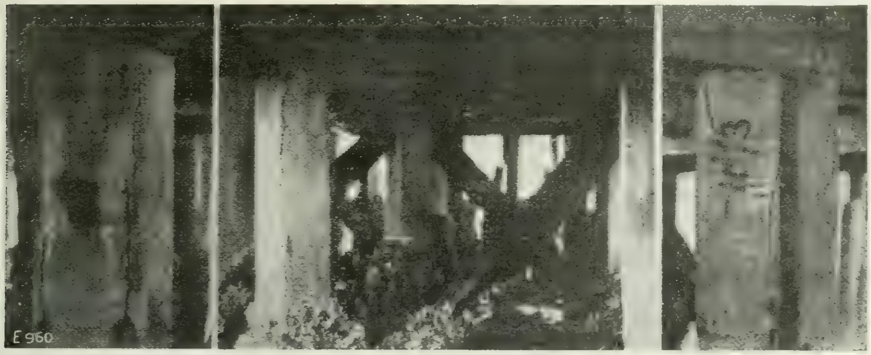


FIG. 16. PRE-CAST PILES CRACKED ABOVE HIGH WATER FROM RUSTED STEEL.

It has been suggested that close proximity of the reinforcing rods to the surface has produced corrosion. In an article in *Engineering Record* of January 25th, 1908, p. 105, there is a description of a reinforced concrete building which was torn down six years after erection. Here it was found that corrosion of the reinforcing had occurred in the columns where the hoops were closer than $\frac{3}{4}$ in. to the surface, and the necessity of keeping the steel "at least $\frac{3}{4}$ in. from the surface" is pointed out.

In passing it might be noted that the difference between $\frac{3}{4}$ in. and 1 in. of covering which the Joint Committee recommends as giving perfect protection against corrosion is a very small margin of safety. As a matter of fact, however, neither $\frac{3}{4}$ in., 1 in., nor, in many cases, even 3 in. of concrete will ensure the embedded reinforcing against corrosion in marine structures. In a number of the piles of the pier previously mentioned where the concrete was proportioned 1 : 1½ : 3 it was observed that some of the rods which had spalled off the concrete were embedded 2½ in. (see *Fig.* 15) and were badly corroded, and in many other structures where advanced corrosion of the reinforcing was found the metal was embedded more than 2 in. When the metal is near the surface it will corrode much more rapidly than when embedded to a greater depth, but the thickness of covering must be much more than has been commonly supposed.

Perhaps the most popular theory of the cause of corrosion of metal embedded in concrete is that of electrolysis. A few years ago this was the explanation advanced for practically all the ills of reinforced concrete, and in some cases it was made to apply to plain concrete also. Naturally the corrosion of reinforcing in marine structures was attributed to this cause, and a number of cases were diagnosed as electrolysis with little more than a superficial examination. In other cases the examination has been carefully made, but lack of any better explanation than that of electrolysis and the firmly fixed idea that 1 or 2 in. of concrete thoroughly protects the reinforcing from corrosion have led the investigators to adopt this theory.

This seems to have been the case in the second report of the Committee on Reinforced Concrete of the British Institution of Civil Engineers. This report contains descriptions of a number of reinforced concrete structures subject to sea-water action. Most of these show extensive cracking of the concrete along the lines of the reinforcing rods. The suggestion is made that the trouble arises from several causes—closeness of metal to the surface, improper placing of concrete, causing porous sections, and lack of bond along the plane of reinforcing—but if there is electric current near the structure it is made to take a large part of the responsibility for the failure.

There probably have been some instances where electrolytic action caused the corrosion of reinforcement in marine concrete structures, but such cases are very infrequent, and the effect from this action is different in one very marked particular from that which is occurring in practically all reinforced concrete in sea water which is deteriorating.

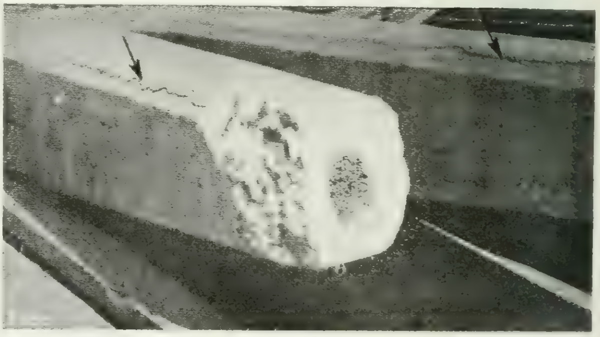


FIG. 17. THIS PILE WAS ON BEACH HIGH ABOVE WATER, BUT CRACKED FROM POROUS PERCOLATION AND SUBSEQUENT CORROSION.

The cracking of the concrete in sea water always starts *above the high-water line*, although it may extend a little below this point as corrosion develops. Very seldom is it found to go down as far as the elevation of low water, and then only when the reinforcing is deeply embedded so that the spalling effect extends a considerable distance below where the metal is affected.

This condition was also noted in the report of the British Institution, and it effectually disposes of the electrolytic theory. In all the experiments made to determine the action of electric current on reinforced concrete it has been found that cracking due to the corrosion of the reinforcing starts where the current leaves the rods. Therefore if electrolysis were the cause, the corrosion and cracking must occur below the elevation of high water, where the current leaves the metal. In a reinforced concrete marine structure in which the corrosion and deterioration do not extend below the water line electrolysis cannot possibly be the cause. For this reason also the corrosion of the reinforcing referred to in the report of the British Institution cannot be caused by electrolysis, for it is stated that the cracking of the concrete occurs above the level of high water.

At Long Beach, Calif., a large number of reinforced concrete piles were cast in 1911, the intention being to use them in constructing a pier. After the piles were cast the work was stopped. The concrete piles have remained where they were cast, about 50 ft. from the shore, without covering and without any electric current near them. The tide never rises high enough to reach the piles, and so they are constantly dry except from such wetting as they get during the rainy season. Evidently the piles were moulded in two operations, one set being of a little better quality—apparently because of the use of a somewhat drier consistency of concrete.

Practically every one of the set made from the very wet concrete has cracked. (*Fig.* 17.) Cracking has not yet developed in the set made of the drier concrete. Certainly electrolysis cannot possibly be the cause of the corrosion of the reinforcing rods. Fresh water was used in mixing the concrete.

Another very good bit of evidence that corrosion of reinforcing with resultant cracking of the concrete is not due to electrolysis was found in one of the rivers emptying into the Atlantic Ocean. At the mouth of the river there is practically undiluted sea water. About fifteen miles from the mouth the water is just perceptibly brackish, and ten miles farther up the river the water is fresh. In this river there are more than twenty-five beacon lights, and these extend from the mouth to a point beyond where the fresh water is always found. The supports for these lights consist of four pre-cast reinforced concrete piles supporting a reinforced concrete slab deck to which is attached the superstructure, consisting of steel members or pipes in the form of a tower. This supports the beacon light. All of these lights burn gas or oil, and none of them is operated by electricity; nor is there any electric current near them. In all cases the deck slab is at least 6 ft. above the high-water line, and in a number of the structures it is 10 or 12 ft. above this point. Knee braces were used frequently to stiffen the deck slab.

A very careful examination of these structures showed that not one of those situated in fresh water was cracked or deteriorated. Holes drilled through the concrete into the reinforcement proved that no corrosion whatever had occurred. On the other hand, every structure below the point where brackishness of the water could be detected was cracked from the corrosion of the reinforcing, the action being markedly more severe as the salt content of the water increased. All of these structures were built about the same time, during 1912 and 1913, by the same contractor. The same materials were used for the concrete for all the structures, and it was of excellent quality. It might be mentioned also that fresh water was used in gauging the concrete. All the cracking was above the water line, and in many of the structures the deck slab and knee braces are the most affected.

Undoubtedly the real cause of the trouble is the accumulation of salts in the pores of the concrete above the water line by capillarity and evaporation and the absorption by the concrete of air carrying very minute particles of sea water. Moisture in this form is transported by the wind a much greater distance than is usually believed. This is shown by the presence of chlorine in the form of sodium chloride. If the moisture from the sea were simply in the form of water vapour from evaporation there would be no salt found in the atmosphere. The studies made on this subject by the United States Geological Survey indicate that finely divided salt spray from the ocean is carried by the air a distance of many miles inland. This probably accounts for the sodium chloride Mr. Harrison found in some of the concrete in the Philippine Islands.

Chlorine and oxygen together form a very active corroding agent. Of course, this has long been known, but what we did not before appreciate was that the salt air could penetrate concrete to anything like the depth it really does.

When steel corrodes it occupies about twice its previous volume. The expansive force thus developed by metal embedded in concrete is enormous, and the concrete is soon stressed sufficiently to cause cracking.

The question has been raised as to whether the cracking comes first and the corrosion is a secondary action which in turn further develops the cracking, or whether the primary cause of the trouble is the corrosion of the reinforcing, with cracking as a secondary action. Of course, if structural cracks occur, local corrosion of the embedded metal may be accelerated. A number of conditions were observed, however, which seem to furnish conclusive evidence that structural cracking is not the fundamental cause of the trouble, but that the reinforcing corrodes first and this causes the concrete to crack. The cracking is always along the lines of reinforcing, and very frequently no other cracks could be found in the member. It seems probable that if cracking had started first it would be more widely distributed.

Usually when a pile is affected all four corners tend to spall, and if one pile in a structure is cracked many others will be found in a similar condition, and the beams and slabs, if of reinforced concrete, will also be cracked. It is conceivable that in removing the forms from a pile a corner, if the concrete is green, may be slightly cracked; but it is not probable that all four corners would be cracked, and it is still less probable that such careless work should be done throughout the structure. As a matter of fact, most of the structures which were examined and found cracked were built by competent, experienced contractors under rigid inspection. During the construction of one of the piers referred to in the early part of this article, in which cracking has been very extensive, one of the authors had an opportunity personally to observe the work during construction. It was done quite as well as if not better than is usually the case; in fact, the firm which had the contract is noted for the excellent quality of its work.

PILE FAILURES NOT DUE TO SHATTERING.

It has been suggested that the cracks in concrete piles are caused by shattering of the head during driving. This cannot be the case, for most frequently the cracking does not extend to the top of the pile, and many of the piles observed were jetted into place.

There is one pier in the southern Atlantic which is supported on Braxton piles. These piles are made with a heavy cast-iron shoe at the bottom which projects beyond the shaft of the pile. The pile is driven by means of a sleeve which is threaded over the concrete and rests on the shoe, so that the driving is done on the shoe and not on the concrete. A number of piles in this wharf are cracked over the reinforcement.

Of course, the cracking of beams and slabs cannot possibly be accounted for in this way. If the cracking is the first action which takes place it is most probable that some indication of this action would have been observed in the beacons in fresh water previously referred to. As was stated before, no evidence of cracks in the concrete could be observed in these. In most cases the cracking stops at the high-water line or a little below it. This is a striking characteristic of the phenomenon. It is inconceivable that if the cracks occurred first they would always be in the same place. The supposition that the corrosion of the metal is originally caused by cracks in the concrete must be dismissed. The metal first corrodes and then the concrete cracks.

It is very significant that the cracking does not extend below the high-water line. The reason for this is probably because the air does not as readily penetrate the concrete below this point.

METHODS OF PREVENTING DETERIORATION.

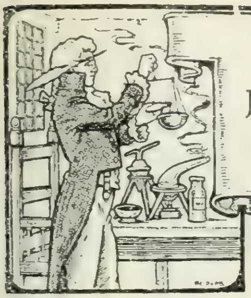
Just how to overcome the widespread deterioration of reinforced concrete caused by the corrosion of the embedded metal is a difficult problem, and the exact treatment and method to be followed will depend upon the exposure conditions, design, and location of the structure. The use of rods of smaller diameter seems to have a beneficial effect. Increasing the distance of the reinforcing from the surface also assists greatly the resistance to corrosion. In pre-cast piles the added weight due to increasing the covering of concrete over the reinforcing must be considered. In many cases the stresses due to bending after the pile is in position are not great above the water line. This condition may be taken advantage of in designing concrete piles for marine structures. For instance, the vertical reinforcing may be bent in toward the centre at a point a little below the water line. Usually ample strength in flexure can be provided by care in the design, and the vertical bearing strength of the pile will be but slightly diminished.

In many concrete structures the members are considerably over-reinforced. This is especially true of piles. Every effort should be made to diminish the amount of reinforcing, and if at all possible a design should be adopted which eliminates the metal entirely for the work above water. Perhaps gravity sections and massive work will cost more in the first place, but the additional expenditure will ultimately prove an economy unless special precautions are taken to ensure the reinforcing against corrosion. Frequently a combination of reinforced concrete below the water line with plain section above will prove best.

If the reinforcing is made non-corrosive by galvanising in the vulnerable part of the structure—that is, above water—the destructive action of the moist air will be prevented or greatly lessened, and the life of the structure materially increased. Painting or impregnating of the exposed parts of a concrete structure will be at best only a temporary expedient unless better materials can be found than those now at hand.

PROPER DESIGN DIFFICULT TO MAKE.

The proper methods to be pursued and the design to be adopted to prevent the deterioration of reinforced concrete subjected to sea-water action depends upon a number of conditions, such as the type of structure, its purpose, the severity of exposure and the climatic conditions. The latter consideration has considerable influence. In warm, humid climates the corrosion of the reinforcing and the consequent cracking of the concrete proceeds much more rapidly than in cool climates where the amount of moisture in the atmosphere is less. It is an interesting fact that reinforced concrete is subject to most rapid attack in localities where plain concrete is but slowly affected by sea-water action, and where the concrete itself is most rapidly disintegrated the corrosion of the reinforcing proceeds more slowly.



SOME ASPECTS OF JOINTS & ANCHORAGE OF REINFORCEMENT.

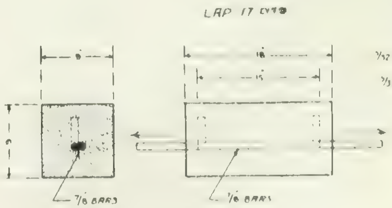
By
R. P. MEARS, A.M.Inst.C.E., M.C.I.,
Bombay

The following notes and diagrams regarding some tests undertaken in India on steel bars will, no doubt, be of interest to engineers generally.—ED.

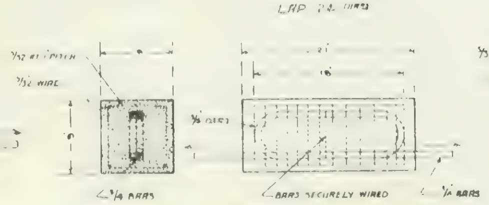
BARS of upwards of 30 ft. in length are difficult and often costly to handle, especially abroad where freight, cartage, and storage have all to be taken into consideration, and, further, such lengths are, as a general rule, not often required, and are very awkward to stock. In beams of any considerable span, especially when it is convenient to turn up bars for shear and to continue them for negative moment, and in any unusual class of work, such as concrete lattice girders, and the like, bars up to 60 ft. or more in length may be required ; also in the tension boom of a lattice girder, where the concrete dimensions are small in comparison to the number of bars to be bedded, very long bars may be necessary, and joints in such tension members may present some difficulty.

In the L.C.C. regulations welding is distinctly discouraged, while in the R.I.B.A. second report of 1911 welding is permitted only if it is really found necessary. In the opinion of the writer these regulations are somewhat severe, as regards ordinary mild steel round bars, for it appears that so long as welds are carefully made and inspected before being inserted in the work, and so long as the individual welds are carefully arranged as to position so as to be well staggered and not to occur at points of maximum stress, and, if necessary, one or more additional bars be put in over and above the number theoretically required to do the work, there should be no possible grounds for prohibiting their use. The writer has tried both hand and oxy-acetylene welding in ordinary round mild steel bars, and has found little difference between the two ; a good parallel weld should break at not less than 85 per cent. of the strength of an unwelded specimen; and if the weld be swelled up so as to present a greatly enlarged section, this portion should prove stronger than the bar—that is to say, when a specimen is tested consisting of a weld swelled to some 50 per cent. or more in excess of its net area, the specimen if tested to destruction should break anywhere in its length other than at the welded portion. The writer has selected many welds which showed signs of being cracked, and were, therefore, cut out as being unfit for use, the worst cases have failed at about 75 per cent. of the strength of the bar, or about 300 per cent. of the ordinary working stress of 16,000 lb. per sq. in., and this appears to justify a maximum stress not exceeding 12,000 lb. per sq. in., measured on the net sections of the bar at the point of weld. Numerous tests on welds have been made by Messrs. Marsland, Price & Co., reinforced concrete specialists, Bombay, under the author's supervision at the chain-testing laboratory of the

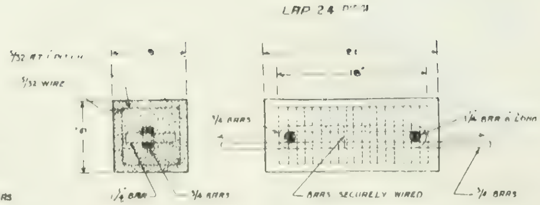
TENSILE TESTS



① FAILED AT 135%
OF WORKING STRESS OF BAR



② FAILED AT 175%
OF WORKING STRESS OF BAR

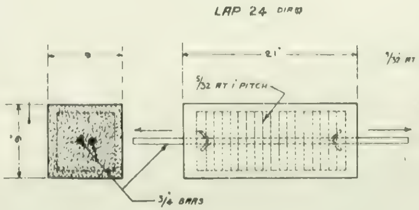


③ FAILED AT 240%
OF WORKING STRESS OF BAR

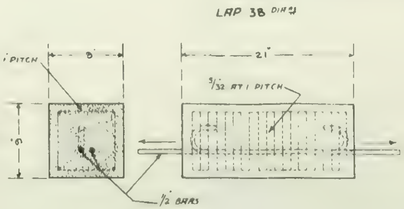
CONCRETE 4 2 1 MIX AT LEAST 28 DAYS OLD
WORKING STRESS IN STEEL 16,000 LBS PER SQUARE INCH

JOINTS IN REINFORCEMENT

NOS ① ② ③ ④ AND ⑤
THE CONCRETE IN EACH CASE FAILED
THE STEEL BARS BEING DISTORTED BUT UNBROKEN
THE AVERAGE OF A NUMBER OF TESTS IN EACH CASE BEING GIVEN

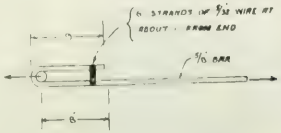


④ FAILED AT 205%
OF WORKING STRESS OF BAR



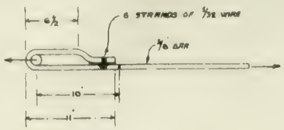
⑤ FAILED AT 180%
OF WORKING STRESS OF BAR

⑥



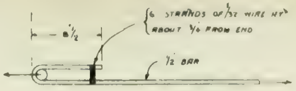
NO CONCRETE
FAILED AT 100% OF WORKING STRESS
OF BAR BY HOOKED END PULLING FROM
WIRE BINDING WITHOUT FRACTURE

⑦



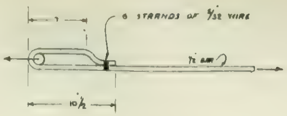
NO CONCRETE
FAILED SIMILARLY TO ⑥ WITHOUT BREAKING WIRE BINDING

⑧



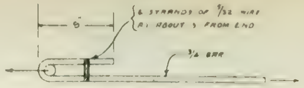
NO CONCRETE
FAILED AT 167% WORKING STRESS OF BAR BY HOOKED END PULLING FROM WIRE BINDING WITHOUT FRACTURE

⑨



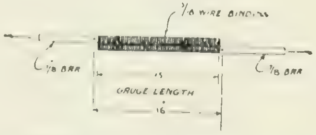
NO CONCRETE
FAILED SIMILARLY TO ⑧ AT ABOUT 100% WORKING STRESS OF BAR

⑩



NO CONCRETE
FAILED AT 167% OF WORKING STRESS OF BAR, WIRE BINDING NOT FRACTURED

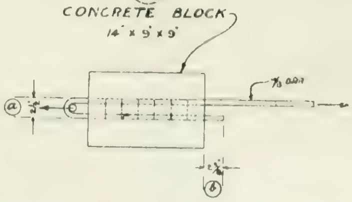
⑪



Nº 2 - 7/8 BARS BOUND TOGETHER FOR A LENGTH OF 15 BY 3/16 WIRE HAMMERED ON WHEN HOT THE WIRE BEING CLOSELY COILED.

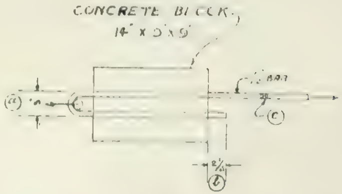
NO CONCRETE
SLIP AT WORKING STRESS OF BAR ABOUT 1/8 TOTAL ELONGATION OF GAUGE LENGTH 2/2 WHEN ONE OF THE BARS BROKE AT 330% OF ITS WORKING STRESS — THE WIRE BINDING BEING UNBROKEN

⑫



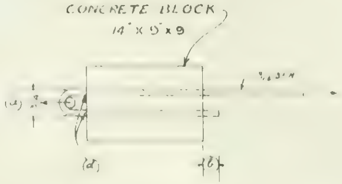
FIRST SURFACE CRACK IN CONCRETE AT 185% OF WORKING STRESS OF BAR AND ON INCREASING THE LOAD THE CONCRETE BLOCK FAILED—OWING TO THE DIAMETRE OF THE PIN BEING LESS THAN THE DIAMETRE TO WHICH THE BAR HAD BEEN BENT THE DIMENSION ⓐ BECAME 2¼ AS THE LOAD INCREASED AND DIMENSION ⓑ REDUCED TO 2". FAILURE OF CONCRETE AT ABOUT 280% OF WORKING STRESS OF BAR — BAR BEING UNBROKEN

⑬



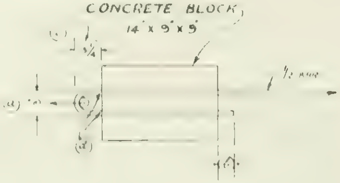
PIN OF LESS DIAMETRE THAN BEND OF BAR, AT 140% OF WORKING STRESS OF BAR THE DIMENSION ⓐ BEGAN TO DECREASE FINALLY BECOMING 2⅛"; DIMENSION ⓑ DID NOT ALTER THE CONCRETE BLOCK REMAINED INTACT AND THE ½" BAR BROKE AT (c) AT 425% OF ITS WORKING STRESS.

⑭



DIMENSIONS ⓐ & ⓑ UNCHANGED THROUGHOUT, AT 268% OF WORKING STRESS OF BAR SLIGHT CRACKS DEVELOPED IN CONCRETE AT (d) THE BAR FINALLY BROKE WITHOUT ANY FURTHER DAMAGE TO THE CONCRETE AT 380% OF ITS WORKING STRESS

⑮



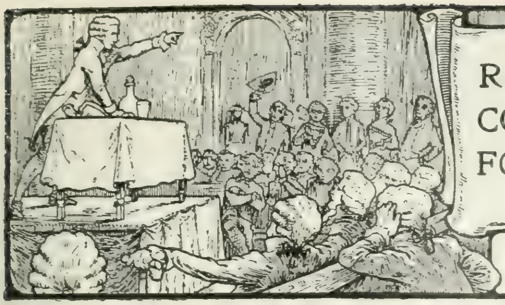
AT 210% OF WORKING STRESS OF BAR CONCRETE BEGAN TO CRACK AT (d). FINALLY DIMENSION ⓑ REMAINED UNCHANGED DIMENSION ⓐ BECAME 2⅛" ⓒ BECAME 2 AND THE BAR BROKE AT 435% OF ITS WORKING STRESS WITHOUT FRACTURING CONCRETE BLOCK

Bombay Port Trust, and independently by the Professors of the Poona Engineering College, to whom the author takes this opportunity of expressing his indebtedness.

The accompanying diagrams (*Figs.* 1 to 5) show numerous attempts to obtain some data as to the reliability of joining bars inside a concrete block by means of lapping, hooked ends, split ends, and ends anchored over pins, but all proved unsatisfactory, the best failing at roughly 250 per cent. of the working stress, the section of the concrete block was not in excess of 9 in. by 9 in., in order that it might be accommodated in the testing machine, and for similar reasons the length had to be limited ; this block of concrete was taken to represent the tension boom of a lattice girder —the concrete in each case was of a 1 : 2 : 4 mix, and not less than twenty-eight days old. The tests showed that any such method of joining bars in a limited concrete section is very unreliable.

Figs. 6 to 11 are tests on single bars lapped over pins without being encased in concrete and proved that such a method of anchorage has some value, more perhaps than would be expected.

Figs. 12 to 15 show that bars may be successfully anchored if bent round over pins with a returned end of some considerable length, and, as in no instance did any of the bars tested break where turned over the pins, it proves that a bar anchored in this manner may be worked at its full working stress. That is to say that the rods in the diagonal tension members of lattice girders may be stressed to their full working load, provided that they are hooked over pins, and have a returned end of length not less than about twenty diameters, the pins also should exactly fit the curve of the bend in the bar. It is desirable that the diameter of the pin be in excess of the diameter of the bar to be anchored, all bends being carefully inspected before insertion in the work.



RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

THE CONCRETE INSTITUTE.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE CONCRETE INSTITUTE.

REINFORCED CONCRETE SHIPS.

By A. ALBAN H. SCOTT, V.P. Society of Architects.

The following is an abstract from a paper read before the Concrete Institute on May 9th—the author illustrated his paper by a number of interesting slides. A short report of the discussion which followed is also given.

DURING the period of the war the value and adaptability of reinforced concrete for a large variety of purposes have often been demonstrated, and at last a serious trial is being given to it for the construction of boats, which, if at all encouraging in results, will open up an almost illimitable field for the future.

The work done by the Concrete Institute on the L.C.C. Regulations in their draft form and since ought to be of considerable assistance in the study of ship construction in reinforced concrete.

Portland cement, the most important ingredient of concrete, is no new material to the steel shipbuilder, as it has for a long time been used as a substitute for paint or as a paving which protects the plating from attrition and corrosion. In certain parts of a steel ship, where oil paint would be difficult to apply, cement wash has been used for a number of years. The uses to which Portland cement and concrete have been put in steel ships and the functions performed by such material are simple compared with those involved in reinforced concrete ships, and the rich proportions used up to the present time have probably had some influence in deciding upon rich mixtures for the reinforced concrete ships. Concrete intended for reinforced work, however, serves a purpose so entirely dissimilar that the former proportions have no relation to the proportions used for the reinforced concrete work.

The approximate number of bars in a reinforced concrete vessel (same D.W.) would be 52,000.

As in all new forms of construction, a large number of suggestions are being put forward for the combination of reinforced concrete with other materials.

Serious proposals have been put forward, of which the following are typical :—

1. The bottom and upper decks being constructed in reinforced concrete with connecting frames of the same material, but the sides of the hull formed of steel or wood or a combination of these materials.
2. For constructing certain portions of the vessels with unit parts by applying slabs of concrete (as plates of steel are applied), at the same time endeavouring to obtain monolithic construction.

THE TESTING OF MATERIALS.

Mr. Campbell Holmes stated in his book that the quality of cement is not often tested in the shipyard, and "it is not unlikely that where small quantities are indirectly supplied much of it may be inherently bad, which may not be discovered for years afterwards."

The testing of materials for reinforced concrete ships is one of extreme importance, and the Concrete Institute's report on this subject should be carefully studied. The whole of this report is applicable to shipwork, except that the maximum size of the coarse material requires, in the opinion of the author, to be reduced to ⅜ in.

Additional tests are desirable as to the impermeability of concrete, and also as resistance to shock.

Although a large amount of experimenting and testing on reinforced concrete has been carried out, much remains unknown when compared with ascertained data from research work undertaken on other materials, and until additional research is undertaken it seems to be inviting disaster to use a very thin concrete of very rich mixtures for shipbuilding work without more knowledge of the true properties of one of the most important materials we are dealing with.

The necessity for checking the strength of the concrete immediately after placing in position is so important that probably the artificial seasoning of concrete specimens by steam under pressure will have to be resorted to in ship construction, as by this means any weakness can be more quickly discovered. Much work remains to be done before this accelerated "ageing" test can be considered to afford standardised data for guidance.

PROPORTION OF CEMENT IN CONCRETE.

It would appear that the tendency regarding ship construction is to increase the proportion of cement in the concrete for the purpose of obtaining additional strength and thus reducing the amount of concrete required. There is, comparatively speaking, little known on the question of concrete with its ordinary mixture equivalent to about 3-5-10, but there is less reliable information on concretes of very rich mixtures, except it is well established that the expansion and contraction, with consequent liability to hair-cracks, are much more pronounced in the richer mixtures than in the mixture mentioned above.

Entirely new conditions occur when dealing with steel embedded in concrete of a very rich mixture, and at this early stage it would seem a mistake to develop too quickly on to the concrete with a larger proportion of cement; and another point entering into consideration at this stage is the minimum thickness of concrete permitted so that it will perform the various functions it is called upon to undertake.

Thickness of Concrete.—If we take slab work with only one-mesh reinforcement the concrete has to be of sufficient thickness to act as a column in compression and to hold the steelwork in its true position under bending. The author would consider a ¾-in. covering over all bars to be desirable, and, assuming a slab was made up with a mesh of ⅜-in. diameter bars running both ways, this would give the required thickness of 2¼ in., and, assuming the meshes were interlaced in the form of basket work, it would give a thickness of 2⅝ in. Immediately we develop into double meshwork the minimum thickness would work out to about 4 in.

Apart from the question of the least thickness required to cover the bars from the points of view of proper adhesion and for general stability, the author thinks the minimum thicknesses should be 3½ in. for slabwork and 4 in. for beams and framings. Working with this thin construction, it is essential that all concrete, where it changes from one direction to another (such as a beam to a slab), and all internal and external angles, should be filleted and, if economically possible, rounded.

It is found in testing concrete that the least satisfactory construction occurs at the internal angles, and it is actually at these points where a good deal of condensation takes place; and on the bottom, next the beams, a good deal of water accumulates, forming a catch-pit and position for corrosion.

The impermeability of concrete is of the greatest importance, and what may be gained on this point by using the richer mixture might be all sacrificed owing to the hair-cracks referred to elsewhere; therefore, rather than use at the present stage a rich mixture to obtain the results desired as to impermeability, it would be better for the moment to devote some attention to obtaining a material which could be applied to the surface of the concrete in the form a wash of specially prepared tar or other bituminous material; if a coat of this description be properly applied, impermeability for many years should be secured. Even if the whole of the external surface of the vessel is not treated in this way, it would certainly be advisable to treat that portion subjected to weather and tide.

INSPECTION AND SUPERVISION.

In the construction of reinforced concrete, whether for land or water use, it might be borne in mind that this is one of the few constructional materials which cannot be properly and fully inspected after the completion of the work. Careful and intense personal supervision is therefore essential to ensure, first, that your steel is placed and maintained in correct position during the progress of concreting ; secondly, that your concrete is properly mixed ; and, thirdly, that it is properly punned and rammed into position.

Supervision should be sufficiently vigorous to ensure that the whole of the concrete is equally mixed and that the punning and ramming are efficiently executed ; even under the best conditions concrete may vary very considerably in composition and strength, and for this reason it is necessary in the design of ship construction and in land structures in reinforced concrete that a greater factor of safety should be allowed than is usually advocated.

POURED CONCRETE.

In several references to reinforced concrete ships one notices the phrase that "concrete is poured in," and in the opinion of the author the loose application of this term should be combated. To obtain the best results, concrete should be *placed* into position as dry as possible, and after the concrete has been so placed and sprinkled with water the result is a material much stronger and much more waterproof than a wet, sloppy mixture, or even a mixture which might be termed plastic ; for this reason one would much sooner adopt the method of elevating the practically dry mixed material in preference to delivery by gravitation.

In reinforced concrete one should not look upon the concrete work as a plastic material that can be poured, but rather as a dry material that has to be raised to efficiency by the admixture of water in small doses after the dry material is in its final position.

The condition in which the concrete is placed in the structure has some influence upon the most economical and the best method of laying out the plant for the construction of the work, and in this connection we might for a moment consider in a general way the most convenient locality for the construction of the reinforced concrete vessels.

SITE.

A good deal of discussion has been taking place as to the suitability of various sites for the construction of reinforced concrete vessels. It is necessary to consider first the materials involved. If we take a boat of, say, 1,000 tons D.W., we find we shall require approximately 40 tons of clean, fresh water, free from injurious foreign matter, 564 tons of aggregate, 234 tons of sand, 125 tons of cement, 160 tons of steel, and 138 tons of material for equipment in the way of machinery, etc. It is clear, therefore, that the combined weight of the sand and aggregate is 66 per cent. of the total required, including equipment. It would consequently appear desirable, so as to save the cost of freightage and the difficulties of transport, that waterways for these shipyards should be looked for in the neighbourhood of suitable stone quarries, where crushing plants could be put down and trolley-ways or rope-ways for transporting the material from the quarry to the shipyard could be arranged. It is also possible that cement could be obtained in the immediate district. If concrete in a relatively plastic condition be finally chosen such a method of transport from the quarries to the vessel obviously suggests that the material should be lifted above the ships, and after being mixed at a convenient level the concrete should be transferred by gravity to each particular vessel and part of the vessel requiring concrete at the moment. This method, however, the author suggests, requires too great a percentage of water.

If the drier mixture of concrete is used, the concrete should be partly mixed on a low level and elevated to the positions required.

The external centering for reinforced concrete vessels will eventually be made movable in fairly large sections, and the plant lay-out for the concrete should be arranged in conjunction with the plant, necessary for easily removing the external centering, by overhead gearing or by rails on the ground level, so as to take it clear of the boat while she is being launched, after which the centering can be run into position again, ready for the next standard boat to be constructed. The internal centering would be moved by overhead gearing and stored in a convenient position, also ready for the next boat. It might even be necessary to construct these boats in a dry dock if their size comes approximately to 5,000 or 6,000 tons D.W. The objection as a rule to using dry docks for the purpose of construction is the comparatively small output of tonnage in relation to the capital expenditure on the dock, but the speed of constructing reinforced concrete vessels at a properly laid out yard for standard designs might justify the expense of a dry dock, in view of the reduction of the cost and the minimising of risks involved in the floating of these vessels.

SHIP LINES.

With this new form of construction for vessels the temptation to depart from true ship lines must be resisted. For many years investigations have been carried on to ascertain the lines which give the least resistance to a ship passing through water ; and because a different material is proposed to be used for certain boats it is submitted a great mistake would be made by departing from proper and regulated lines of the ship in the expectation of securing economies in construction in reinforced concrete. Safety and efficiency in running must be the first considerations. To depart from proper ship lines would involve extra expenditure on the running costs, which would quickly neutralise any saving on the capital outlay of the ship when constructed.

WEIGHT OF CONCRETE.

It is found that the weight of concrete varies considerably, according to the kind of aggregate and proportions used, but for all practical purposes for land work it can be taken at 148 lb. per cu. ft., but for ship construction it should be taken at 156 lb., to which should be added the weight of the reinforcement in each case.

The concrete for such thin constructions as used in reinforced concrete vessels, if properly executed and with aggregate not exceeding $\frac{3}{8}$ in., the weight per cu. ft. will be found to average about the weight given above.

STANDARDISED REINFORCED CONCRETE SHIPS.

It is not proposed in this Paper to deal at length with the question of standardising for reinforced concrete ship construction, as the author feels that those used to reinforced concrete require no convincing on this matter, and those who are used to steel ship construction are referred to a paper recently given by Sir George Carter, K.B.E., at the Institute of Naval Architects, where practically all his arguments in favour of standardised steel cargo boats apply equally to reinforced concrete boats. One advantage he mentions is so applicable to reinforced concrete boats that it calls for quotation here :—

" All the steel scantlings, after being settled in the ordinary manner, can be carefully examined to reduce the number of steel sections in the ship as much as possible. This results in producing the fewest changes of rolls at the steelwork and in the rolling of much larger parcels of materials to the one pattern on account of the large number of ships that are to be built to this design.

" As an example of this, in the standard ships now built the number of sections are reduced to 8 or 10, as against 30 to 40 used in pre-war days for the same type of ship."

In the reinforced concrete boats it would probably be possible to confine the diameters of the steel rods to six sections only.

Every bar, no matter what its diameter and no matter what its function may be, should have hooked ends, the hook being equivalent in radius to not less than five times the bar diameter ; these hooked ends should not, under any circumstances, take the place of the necessary overlap required to get continuity of the bars, but should be an additional precaution to such overlap. Fish tailing or split ends of bars should not be allowed.

The usual method of welding steel bars should not be resorted to with steel intended for reinforced concrete structures for land or water use ; the only satisfactory welding is the electrical welding, executed with proper plant and proper machinery. This should *not* be carried out on the actual job.

VIBRATION.

The proper connection and continuity of rods will have very material relation to the effect of vibration and shock on reinforced concrete work.

In shipping construction the vibration may be considered continuous, and the effect of such continuous vibration on the adhesion of concrete and steel has not yet been ascertained ; it can only be arrived at after a good many years of actual service. It is suggested that a good deal of the vibration caused by the engines and other machinery can be considerably reduced by the introduction of special anti-vibration foundation work, suitable for the plant, which will be installed in a ship, where one meets with the bases considerably less in size than is the case with plant of the same power in land structures.

It is not probable that concrete would be disintegrated by the continual vibration, but the adhesion of metal to concrete certainly might be affected, and it should be remembered that whereas some degree of plastic deformation may be expected in steel under stress, concrete, even if elastic, is certainly not plastic in the same sense as steel. There are but few real data as to the effect of shock loads on reinforced concrete ; the tests carried out in Italy some years ago are interesting studies in this connection.

FIRE-RESISTANCE.

Whilst dealing with the effect of shock on reinforced concrete, the question of the fire resistance of concrete should be considered. The claim that reinforced concrete is *fireproof* is quite erroneous. It is *fire-resisting*, and the effect of fire on reinforced concrete is not developed so quickly as it is on steel, and undoubtedly it will carry considerable loads without deformity whilst at a high temperature, which steel will not do.

With such a thin protecting coat of concrete, as we get in reinforced concrete boat work, it is necessary, both from a structural and fire-resisting standpoint, to have the steelwork well tied in, connected double-mesh work where possible, and extra care taken at all junctions ; all arrises should be rounded or splayed. Properly designed and erected reinforced concrete work has undoubted claims over unprotected steel construction, and in arriving at the rate for insurance against fire the underwriters ought to take this into account ; on the other hand, however, with grain cargoes any effect from swelling would have a more serious result on reinforced concrete than on steel owing to the steel boat having greater elasticity. It must not be taken that reinforced concrete construction has every advantage and no disadvantages, but the efficiency as a whole must be considered.

WHAT IS THE MOST EFFICIENT CARGO BOAT ?

What is the most efficient cargo ship ? Assuming that the ship is seaworthy, the greatest economic value is obtained by a combination of the greatest registered tonnage that can be carried and conveniently handled and the cost of running at the required speed, together with the capital cost and the cost of upkeep.

The author is given to understand that most of the canal and dock dues are reckoned on the registered tonnage ; therefore the reinforced concrete boat is not at a disadvantage on this particular point owing to its extra displacement. The cost of upkeep of a vessel depends so very much upon the uses to which it is put and the trade routes used, that it is difficult to get absolutely definite data for upkeep ; but, always assuming that the boats are seaworthy, reinforced concrete would in all cases cost very much less for unkeep than a steel or wooden boat. The comparative horse-power required for timber, steel, and concrete boats unfortunately shows considerably increased horse-power required for reinforced concrete for the same D.W. ; but against this must be placed the lower capital cost and the reduction in maintenance ; and the point also must not be forgotten that there is big economy secured through the much greater speed in which concrete hulls can be built as compared with steel or wood hulls.

CONCLUSION.

In conclusion, the author asks to be allowed to quote the first paragraph in the preface of a book * referred to in the course of the Paper :

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* "Reinforced Concrete in Practice," by A. Alban H. Scott.

"Whilst the author is of opinion that there is no form of building so lasting, and requiring less maintenance than reinforced concrete, he considers it should only be employed when the work is under constant, careful, and experienced supervision, and when every material used in the work is tested."

There are some wonderful steel ships, there are also wonderful reinforced concrete buildings, and with the joint efforts of the naval and land architects there ought to be some wonderful reinforced concrete ships.

DISCUSSION.

Mr. H. N. Sporborg, Chief Engineer of the British Thomson-Houston Company, Limited, was unable to attend, but wrote : "It is a commonplace to say that engineering experience with reinforced concrete has been almost entirely confined to land or stationary uses, but that fact by itself lends great weight to Mr. Scott's warning to those who propose to use it for water or floating work not to fail to make the utmost possible use of experience already gained with reinforced concrete in stationary work. Such experience has now become very great—even the war having added very considerably to the sum total—and speaking broadly the results so far attained having been so very successful, there is very solid ground work to build upon when facing the new problems involved in the fabrication of ocean vessels from this material.

"When considering the question of stresses to which the hull of a concrete ship will be subjected, t must not be forgotten that the advent of the modern high speed turbine and either the electric or the double helical gear drive of the propeller make it possible to eliminate reciprocating parts from the propelling machinery of the cargo boat of the future. Such development means that the concrete ship need not be subjected to the pounding action of constantly repeated frequent shocks which in time causes disintegration of concrete.

"Judging from actual experience with reinforced crane gantrys, carrying heavy travelling cranes, which are provided with wooden sleepers under the crane rails, the use of wooden machine beds under heavy reciprocating pumps, etc., should eliminate any bad effects on the structure from machinery vibration.

"There still remains, however, the one great uncertain factor of the effect on the hull structure as a whole of the twisting or torsional stresses of a heavy sea-way on the ship's quarter. Such stresses lie entirely within the purview of the naval architect, and can best be met by actual experience and the whole-hearted co-operation between naval and land architects and engineers which the author so eloquently urges.

"These problems once solved, the advent of the concrete ship should take us a long step forward in the direction of the standard ship, as its proper method of construction postulates the development of building plant particularly adapted to rapid repetition work on hulls of exactly similar design."

Mr. R. N. Dana, Secretary of the Institution of Naval Architects, regretted his inability to attend but wrote, saying the subject was one of great interest just now, both to shipbuilders and to civil engineers, and it seemed probable that this new material for construction of ships was likely to assume considerable importance for some time to come. Whether it successfully survived the test of time for the particular purpose would depend largely, in his opinion, on the improvements that might be effected in the composition and manufacture of cement to render it more suitable to resist the heavy and varying stresses to which ships were subjected at sea.

Mr. H. C. Johnson (Cork University) wrote that he believed the heaviest workable mix, ½-in. gravel and buzzard sand plus 30 per cent. cement, was the most economical for concrete ships ; not broken stone.

Mr. Wentworth-Shields, in proposing a vote of thanks to the lecturer, said that concrete ships were a great novelty in this country, but he had no doubt in his own mind that they had come to stay. About 15 to 20 years ago, when reinforced concrete was first to be used in structures in this country, they looked upon it with very great suspicion. It was a most curious combination of materials, one apparently so weak and the other so strong. How were they to pull together ? What was to happen ? And they were especially suspicious of reinforced concrete when placed under water. Time had gone on since then, and they found that as a matter of fact reinforced concrete had become most useful and reliable, and that under water it behaved exceedingly well indeed. He was rather wondering whether the naval architect of the future with his reinforced concrete ships might not have considerable trouble on the water-line between wind and water. That was the place where the naval architect had trouble nowadays, he believed, and it was possible that he might have trouble in the future. He was inclined to think from the experience he had gained in marine works that provided he did what Mr. Alban Scott suggested—namely, give his boats a good coating of some reliable bituminous paint or something of that sort, he would find that his concrete ships would be long lived. The matter of the application of reinforced concrete to ships being so new, there was a great deal to learn about it.

Mr. Barnaby (Southampton), expressing the views of a naval architect and shipbuilder, said he did not think at the present time any concrete ship of any size had been subjected to stresses in a sea way, and, of course, it was that that they were most anxious about. Ten years ago reinforced concrete had been mentioned as a possible material for ship construction ; now they were thinking about reinforced concrete ships, and certainly they had come to stay, at all events, for the duration of the war. How long afterwards he could not say, but they looked to concrete engineers to help them a little in the proper way to calculate the strength of the midship section of a ship in a sea way subjected to alternate waves, sometimes upon the crest and sometimes upon the hollow of the wave. They were told that the steel only was to be taken into account in the tensile strength, and both steel and concrete in the compressive strength. When they considered the section of a ship and tried to get its neutral axis, assuming her on the wave, they took only the steel on the deck and the steel and concrete on the bottom, and they got the neutral axis very near the keel. The next minute, when she was in the trough of the wave, they got a great displacement of the neutral axis. It had been proposed, and he thought, very reasonably, that a special allowance should be made for this. The modular ratio of concrete and steel might be taken as about 8 per cent. ; that was to say, the concrete was about 8 per cent. of the steel, or, in other words, that the steel was 12½ times as strong in its elastic limit as the concrete ; therefore, in calculating the neutral axis of the section, it was now usual to assume that the steel was increased in area by 12½ or 15 ; in taking the neutral axis of them, its net area was only taken into account for the stress upon the material. That was a point upon which he should like Mr. Scott's opinion. If they overlapped about 40 diameters, the grip of the concrete was quite equal to the strength of the steel he believed, but if a ship was built in a hot climate and came into a cold one, the grip might be a little reduced, due to the contraction of the steel. Mr. Scott was wise in insisting that all rods should be hooked as well as have a large overlap ; he looked upon the hook as an additional security. He cautioned them not to expect the first reinforced concrete ship of a particular design to be built quicker or even so quickly as a steel one. Launching he did not look upon as such a difficult problem. If concrete engineers could secure reinforcing sufficiently to prevent any displacement of it, it would be much better to use a ship-shape form. One use to which reinforced concrete might be applied with very great advantage immediately in shipbuilding was this. A great number of ships had not sufficient bulkheads in them at present. The Italians were building steel bulkheads into their existing ships, more closely dividing them. The difficulty of getting steel and labour at the present was great ; there was no reason why ferro bulkheads should not be put into ships at the present time with very great advantage to those which were insufficiently divided.

Mr. H. K. G. Bamber, F.C.S., said that the method in which concrete should be mixed and put into position suggested by Mr. Scott in his Paper did not appear to him to be the best to adopt.

Dr. J. S. Owens, B.A., M.D., drew attention to the ease with which a reinforced concrete ship could be repaired if injured ; if she got a lump knocked off her it could very easily be replaced. The factor of safety was really a confession of ignorance on the part of the engineer. In the case of a ship there were a thousand-and-one stresses and tensions which they should never be able to analyse completely. He suggested that instead of setting up a new committee to consider the matter, they might see whether they could not utilise one of the existing committees of the Institute to undertake the work.

Mr. H J. Davies advised the provision of sections in this country sufficient to meet shipbuilding requirements after the war.

Mr. H. J. Deane, M.Inst.C.E., did not think they knew sufficient about the permeability of concrete at the present time. The Institute might do a good deal for them as engineers on that subject. They had heard a good deal about the hydration of cement, but the information came from the enemy. Ship builders should take very special precautions to see that the concrete was kept thoroughly moist after setting. When they got into large construction, it would be found that building ships on launching ways would probably be the most economical.

Mr. Francis Wade considered that the insidious vibration that a ship, when she was alive, was subjected to would be the dangerous factor in the life of a concrete ship.

Dr. Owen Faber, D.Sc , did not want to throw cold water on concrete ships ; they might not stand it. If a concrete ship lasted 10 years, he should consider it had done very well. It would still pay if it only had a life of three years. At the present moment they could build concrete ships, but he did not think they were justified in saying, as they very often did, that a concrete ship was practically everlasting, and, at any rate, had a far greater life than a steel ship. He did not think that was likely to prove to be the case. A concrete ship, roughly speaking, weighed 50 per cent. more than a steel ship, and if they were on the side of safety, they would weigh still more. After the war he thought it would be found that this increase in weight would knock the concrete ship out of competition with the steel ship altogether. There would be a greater coal bill and an increased skin friction.

THE LECTURER'S REPLY.

Mr. Scott, in replying, said that the whole subject was one which required most careful thought and consideration, and the various points raised in the discussion all required going into very thoroughly, which obviously could not be done by way of reply that evening. Mr. Barnaby's kind contribution had placed before them very fully the difficulties from the shipbuilders' point of view, and although he quite agreed with Dr. Faber's remarks regarding the necessity of limiting the number of committees, the matter under discussion, he ventured to suggest, was one which should be dealt with by a committee composed of a certain number of representatives of the Concrete Institute and a certain number nominated by the Institute of Naval Architects and other institutes and bodies interested. It was obvious that one of the existing committees of the Concrete Institute could not undertake the work so efficiently as a special committee on the lines he had indicated.

Regarding the life of a concrete ship, personally he did not think it wise to make any statement as to the probable life of a concrete vessel, as it entirely depended upon the construction, particularly the cover given to the steelwork. With only ½-in. cover, unless there was some external application to the concrete work, the steelwork could not be entirely free from corrosion. In conclusion he desired to thank the various Papers which had kindly given him facilities for producing the lantern slides that evening, and he particularly mentioned CONCRETE AND CONSTRUCTIONAL ENGINEERING, as they had given him a very large amount of assistance in connection with the photographs.

NEW BOOKS
AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

Engineering for Masonry Dams. By Wm. Pitcher Creager, Am.Soc.C.E.

Published by John Wiley & Sons, New York, and Chapman & Hall, London. Price 11s. 6d. net

This book is written more especially for American engineers and deals with many subjects, such as ice pressure, rockfell and timber dams, etc., which do not occur in general English practice, although they will doubtless be of interest to colonial engineers.

Chapter I. deals with investigations and surveys for dams and describes fully the nature of the investigations required and the means employed in carrying them out.

Chapter II. concerns the choice of type of dam and describes the special advantages of several types for different purposes and localities. The types dealt with are :

Solid gravity masonry dams ;
Hollow ditto ditto ;
Arched masonry dams ;
Earth and rock embankments ;
Timber dams ;
Other types and combinations of types.

The author states, with respect to solid gravity dams, that hollow dams require only 35 to 40 per cent. of the concrete required for solid dams and that for a remote location, where materials of construction are expensive, the hollow type will usually cost less than the solid type ; but in ordinary location comparatively near a railway, where there is a good quarry and a sandbank is convenient, the reverse is true. An earth or rock embankment will, it is stated, always cost considerably less than any form of gravity masonry dam if materials for the former are found convenient to the site, but that there are limitations to the employment of embankments, such as the necessity of providing sufficient spillway. With respect to hollow gravity dams it is pointed out that when time of construction is a consideration this type can be constructed in less time than a solid dam.

For a hydraulic power installation the necessary housing accommodation for turbines and other apparatus can be provided inside the dam itself and thereby expenditure may be saved. Where there is considerable uplift the hollow dam has a distinct advantage as the water has a direct exit under the dam.

The author considers the fact that the resultant of all forces falling very nearly at the centre of the base is an advantage for this type more fanciful than real, since either type, if properly designed, should give no cause for anxiety with respect to overturning.

When the requisite support is lacking in sustaining power the lesser weight of a hollow dam is pointed out to be a distinct advantage for this type.

With regard to arched dams, it is pointed out that suitable sites for this type are seldom found, but that it is ideal when the length is small in proportion to the height and when the sides of the valley are composed of good rock. It is remarked that, as the weight of an arched dam is not counted on as assisting materially in the resistance to external loads, there is always sufficient masonry to resist any possible uplift.

Combinations of arched and gravity dams are stated to be common for sites where the length is too great to permit the adoption of the arched type, such dams being designed to resist the loading by gravity, but are curved in plan and designed with a smaller margin of safety than if straight. Timber dams are stated to be ideal for temporary uses, and if well designed may last for fifty years or more. Maintenance charges are, however, very high when compared with other types. It is pointed out that timber dams are seldom very tight, and that, in fact, a small leakage is necessary for the preservation of the timber.

Amongst the other types of dams, structural steel dams, peculiarly shaped masonry dams and movable dams are mentioned.

Chapter III. deals with the forces acting on dams, etc. :

(*a*) Water pressure.
(*b*) Earth pressure.
(*c*) Atmospheric pressure.
(*d*) Ice pressure.
(*e*) Wind pressure.
(*f*) Wave pressure.
(*g*) Weight of dam.
(*h*) Weight of the foundation.
(*i*) Reaction of the foundation.

The methods for assessing these various forces are entered into in detail and the necessary equations for the purpose of design are fully set out.

It is stated that the bevel to the crest of an overflow length of a dam on the inner side is not considered as being subjected to any vertical pressure when water is passing over the crest, since the velocity of the water is such that no vertical pressure is produced. The horizontal pressure on the level is, however, included, to be on the safe side. It is pointed out that the head of water acting on the dam must be taken far enough back to avoid the surface curve of the water and that an additional head, equal to twice the velocity head of the water, should be added to allow for impact.

If g is the discharge per lineal foot of crest, w_2 the unit weight of water, h_v the velocity head, h the height of the dam to sill level, and h_2 the total depth from flood water level, the velocity of approach is $v_1=\frac{q}{h_2}$, and the total impact pressure on dam is given as $P^1=\frac{w_2 v_1^2 h}{g}$.

It is stated that the stream of water passing down the outer face of the dam does not transmit any pressure to the dam owing to its velocity, neither in every case does the tail water exert any pressure on the dam as its depth is often eliminated by the impact of the falling water, and equations are given for determining when such a condition occurs.

The question of uplift is fully dealt with and frequent references are made to the recent useful paper and discussion before the American Society of Civil Engineers (Vol. LXXV.). The area of base subjected to uplift allowed in various dams is given, and the author concludes that for masonry dams on fair rock foundations two-thirds of the total area of the base is the extreme limit of area to be considered as subject to uplift, and that ordinarily a much lower value may be adopted. He, however, points out that for earth foundations it may be necessary to provide for uplift over the whole area of the base, but that in this case the distance of travel for the water may be considered as the length of the base plus twice the depth of the impervious cut-off.

The author points out that in the case of hollow dams little or no uplift can occur, but sufficient drainage holes must be left in any slab foundation. It is customary to adopt an uplift on all horizontal joints equal to that on the base.

The additional pressure on the dam due to the vacuum induced by the water falling over the crest, if ventilation under the water sheet cannot be provided, is dealt with, and the advisability of fitting the down-stream face of the dam to the lower nappe of the jet is advocated.

Ice and wave pressure are specially referred to and the weight of the dam and foundation and the reaction of the foundation are given full consideration, equations and data being given for their determination.

Chapter IV. deals with the requirements for stability of gravity dams and gives rules for the following :

(1) Location of the resultant.
(2) Inclination of the resultant.
(3) Compressive stresses.
(4) Tension on vertical planes.
(5) Margin of safety.
(6) Design and methods of construction.

With respect to compressive stresses it is shown that the maximum stresses occur on inclined planes. It is recommended that after the dam has been designed to conform to the allowed vertical stresses the inclined stresses be investigated and changes made in the section, if the inclined stresses are found to be too high, and maximum inclined compressive stresses of one-ninth the ultimate strength of the masonry are recommended for adoption. It is further suggested that the following maximum vertical stresses should be adopted in design :

At the toe of solid dams $\frac{1}{21}$ of the ultimate strength.

At the heel of solid dams one-fifteenth of the ultimate strength.

At the heel and toe of hollow dams one-fifteenth of the ultimate strength.

Foundations of bed rock are stated to be stronger than the masonry, but the following values are given for the allowable stresses on earth foundations :

Clay, 8,000 lb. per sq. *in.*

Coarse sand, 4,000 to 8,000 lb. per sq. *in.*

Fine silt, 2,000 to 4,000 lb. per sq. *in.*

" Inch " in this case is an error and should be " foot."

With respect to tension on vertical planes the author refers to the paper and discussion before the Institution of Civil Engineers and comes to the conclusion that, whereas it must not be lost sight of that tension will certainly exist in vertical planes if the inclination of the downstream toe is too great to transmit the loads to the foundations, the fact that a great number of existing dams, if investigated according to Mr. Atcherley's theory, would be found to be quite unsafe, points to the conclusion that there is some error in this theory and that its application imposes too severe a condition on structures of the usual type.

Chapter V. deals with the general equations for design of gravity dams, dividing the height into zones over which various conditions are the ruling factors for the purpose of design.

Seven zones are considered, the ruling factors applicable to each being as follows :

In non-overflow dams the design of Zone I., when ice pressure exists, is governed by rule 2 above (the inclination of the resultant).

In overflow dams, owing to the deficiency in the weight of the top, rule 1 (the location of the resultant) and rule 2 (the inclination of the resultant) will both be violated, but, fortunately, the conditions are not severe and can be easily met by special treatment.

Zone II. covers that portion of the dam wherein the resultants for reservoir full and empty remain within the middle third when, in the case of a non-overflow dam, both the upstream and downstream faces remain vertical, and, in the case of an overflow dam, the upstream face is vertical and the downstream face is a continuation of the spillway curvature.

At the top of Zone III. the resultant reservoir full coincides with the outer extremity of the middle third and the downstream face becomes battered to keep this resultant within proper limits, the upstream face remaining vertical until the resultant reservoir empty reaches the inner extremity of the middle third, determining the bottom of the zone (rule 1 applies).

Throughout Zone IV. both the upstream and downstream faces are battered to the extent required to keep the resultant reservoir full and empty within proper limits (rule 1 applies).

For Zone V. the conditions reservoir empty remain the same as for Zone IV,. being governed by rule 1, whereas for reservoir full the compressive stresses begin to be the governing factor (rule 3) and the resultant becomes further and further inside the outer limit of the middle third.

Throughout Zone VI. the compressive stresses are the governing factor both for reservoir full and empty, and consequently rule 3 is employed to determine the slope of both the upstream and downstream faces.

Zone VII. represents a portion of the dam in which, under the condition reservoir full, the inclination of the downstream face is greater than the limit fixed by rule 4—*i.e.*, there is tension in vertical planes necessitating a rearrangement of the upper zones to produce a steeper downstream face. The inclination of the upstream face throughout this zone continues to be governed by the compressive stresses (rule 3).

Equations are given for meeting the requirements under the several rules 1 to 4, two sets of equations being given—*i.e.* :

(1) " Equation of Determination," with which to determine the length and location of successive joints in conformity with each rule.

(2) " Equation of Investigation," with which to investigate any pre-designed portion of the dam in conformity with each rule.

Chapter VI. contains detailed numerical examples of the design of solid, non-overflow gravity dams, and comparisons are given with dams actually constructed.

Chapter VII. deals with the design of solid spillway gravity dams, special consideration being given to the shape of the crest, the discharge capacity as effected by piers, the form of " bucket " or curve at the toe to deflect the flow. Detailed numerical examples are given and comparisons with dams actually constructed.

Chapter VIII. covers the design of hollow dams with both straight and arched upstream faces and detailed numerical examples are given for non-overflow and spillway dams of this type.

Chapter IX. deals with the design of arch dams. A tabulated statement is given showing the details of dams of this type which have been constructed. It is shown that the most economical central angle between the abutments is 133° 34′. The use of steel reinforcement in a horizontal direction is depreciated, but vertical reinforcement to distribute concentrated loads, such as ice-thrust, and for stiffening the relatively thin upper portion of the dam, is recommended.

It is also recommended that the ratio of slenderness (*i.e.*, the ratio of the curved length of the arch to thickness) at mid-height be not greater than 25, whereas at the top it may be not greater than 75, the ratio at the top being increased if the thickness increases rapidly toward the lower elevations, and the ratio at mid-height is proportionately reduced. This is stated as being particularly true if considerable vertical reinforcement is used, and the case of the salmon creek dam is cited, where the ratio at the top is more than 100, but at mid-height is less than 10.

Multiple-arch dams are given special consideration, it being pointed out that in this type the loading on any arch slice is not uniform, but that the percentage in variation of the loading gradually decreases toward the base of the dam. It is recommended that the arches in the upper part of this type of dam should be circular in horizontal planes, or well reinforced to resist the non-uniform loading. Illustrations are given of existing arched dams showing details of thicknesses, etc.

Chapter X. deals with the preparation and protection of foundations and gives useful advice as to the preparation of the foundation and the grouting up fissured rocks. The precautions necessary to eliminate or decrease the uplift are referred to and the conditions necessary for securing satisfactory earth foundations are dealt with, special consideration being given to the question of under dams on this type of foundation.

Chapter XI. is devoted to the magnitude of flood flows and Fuller's equation —$Q_m = NA^{0\cdot8}\ (1+0\cdot8 \log T)\ (1+2A^{-0\cdot3})$— for the maximum flood in cubic feet per second to be expected in any period of years from any catchment area in square miles (Trans. Am. Soc. C.E., Vol. LXXVII.) is given, together with a useful diagram showing the discharge in cubic feet per second for catchment areas of varying areas in square miles, using Fuller's equation with values of 100 and 85 for the numerical coefficient (N) and 1,000 and 100 years periods (J) during which the flow given by the equation will be only once exceeded.

The diagram also shows the actual discharges of 120 unusual floods and the catchment area from which such floods were derived.

The various conditions affecting the value of the numerical coefficient N of Fuller's formulæ are discussed, the general conditions being :

(1) The prevailing conditions of rainfall.

(2) The storage capacity of the watershed or its ability to retain temporarily and distribute the maximum rainfall.

(3) The capacity of the watershed to suddenly release stored waters.

Each of which has several subdivisions.

The author arrives at the conclusion that little or nothing has been accomplished which would indicate a definite relation between flood coefficients and characteristics of catchment areas, and that, until more information has been obtained, the matter must be left to the judgment of the engineer.

In general, the order in which the several conditions will have most influence on the flood tendencies are as follows :

(1) The maximum rate and duration of rainfall.

(2) The steepness of the slopes in the catchment area.

(3) The shape of the catchment area.

(4) The arrangement of tributaries to the main stream.

The capacity of the stream to release stored waters suddenly cannot be included in a general classification, as their effect on floods is too uncertain.

It is pointed out that Mr. Fuller, in his paper, has given a unique approximate method of determining directly the value of the flood coefficient (N) from a study of the maximum yearly floods on the stream under consideration.

Chapter XII. deals with details and accessories, such as the proportions for the concrete to be employed, contraction joints, drainage systems, architectural treatment, and the regulation of high-water surface by means of gates, flash-boards, syphons, etc.

The book covers the subject dealt with in a very thorough manner and embodies the latest experience and investigations. It can be confidently recommended to engineers interested in the design and construction of masonry dams.

Theory of Structures. By Arthur Morley, M.Sc., M.I.M.E.

London: Longmans, Green & Co. 584 pp. Price 14s. net.

It is doubtful whether the rising generation of engineers realises how much easier it is for them than for their predecessors to study the application of science to engineering. During the last fifteen years there has been a great advance in the standard set of engineering text-books, and Mr. Morley holds a high place among those responsible for that advance.

After publishing one or two elementary though very useful text-books, he published in 1908 his text-book upon "Strength of Materials," which very quickly asserted its position as one of the most successful books upon the subject. This book was characterised by a thorough and rigid method of treatment which appeals with greatest strength to those students who have received a good mathematical training, and yet it is approached from a much more practical standpoint than has been adopted by those writers who have followed more closely the mathematical theory of elasticity.

The book under review was first published in 1912, and its present edition differs very little from the original. The only addition that we notice consists in a treatment of unsymmetrical bending, following the S-polygon construction of Prof. L. J. Johnson and referring to Prof. Cyril Batho's work upon this subject.

The general method of treatment follows upon the same lines as in "Strength of Materials"; in fact, as is natural, a fair amount of the subject-matter is identical.

After chapters upon Stress and Strain, and Working Stresses, we pass to a chapter upon Statics in which most of the now familiar fundamental constructions of Graphic Statics are set out. Next come chapters upon Bending Moments and Shearing Forces, and Stresses in Beams, the next chapter dealing with Moving Loads and introducing the principles of Influence Lines. We pass next to chapters upon Deflection and Elasticity of Beams, the next one being entitled Direct and Bending Stresses and including the theory of Columns; this important subject is dealt with in a succinct but quite excellent manner, and contains some very clever approximations of troublesome mathematical analysis. Mr. Morley is quite a master in the application of successive approximations to rigid mathematical theories.

We then pass to what some people might regard as Theory of Structures proper as opposed to Strength of Materials and have chapters upon Framed Structures; Stresses in Frames; Moving Load Stresses in Frames; Selected Typical Framed Structures; Deflection and Indeterminate Frames; Some Indeterminate Combinations; Frame Members and Structural Connections; Plate Girders and Bridges; Suspension Bridges and Metal Arches; Earth Pressures, Foundations, Masonry Structures.

With such a wide range compressed into one volume much of the treatment is necessarily condensed and some students will find some difficulty in following it, but the book has deservedly had a very good reception and it is one which every structural engineer may regard as demanding a place among his literature of the subject.

The Design and Construction of Industrial Buildings. By Moritz Kahn.

Technical Journals, Ltd. 7/6 net.

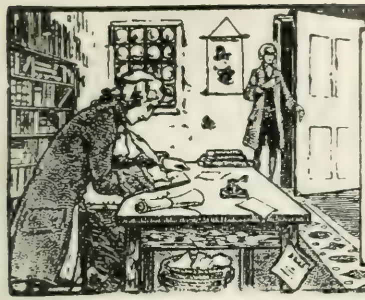
During the past three years the chief activities of the building trade have been employed in the erection of factories and temporary buildings, and owing to more intensive production and more thorough organisation it is most probable that the next few years will also witness many building and reconstruction schemes involving factory and industrial buildings.

The books and pamphlets published on this subject are relatively few in number, and we therefore welcome this volume, which in a small compass deals with the essential matters to be remembered in laying out and constructing manufacturing buildings.

The author, as a leading exponent of reinforced concrete construction, betrays a natural bias against any other form of work, and we cannot always agree with his opinions.

The book commences with general considerations as to factories and briefly analyses the various types of structures in common use. Construction, lighting, heating, ventilation, plumbing, and architectural grouping occupy separate chapters, and a short synopsis of the place and effects of welfare work in the factory organisation is included.

The volume is illustrated with diagrams and photographs of recent factory buildings, most of which are of American origin; and, although industrial methods across the Atlantic are somewhat different from our own, the examples set forth are worthy of study. This applies especially to the elevations, for in normal cases in this country building Acts would prevent the provision of the large spaces that seem to be the rule in America. Both the printing and appearance of the volume are excellent. We can recommend this book to all interested in this important subject.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

British Scientific Products Exhibition, 1918.—We beg to draw the special attention of our readers to the above Exhibition which, with the assent of the Ministry of Munitions and the Board of Trade, has been arranged by the British Science Guild, and is being held at King's College, Strand, London, W.C. (August 12th to September 7th).

The chief purpose of the Exhibition is to make clear the necessity of Scientific Research with respect to the application of its results in the arts and industries ; and, further, to display to the public and to those intimately concerned how much has been successfully achieved in this regard since the advent of the war in the production of articles of prime importance not only for the home but also for foreign markets hitherto manufactured in or imported from other countries.

Reconstruction in Dublin.—The materials of construction used in the rebuilding of the area destroyed by the Irish Rebellion of 1916 are almost entirely of a fire-resisting character, and two of the largest buildings now in course of erection—namely, the Scala Theatre and Eason's stationery house—are being built in reinforced concrete on the Mouchel-Hennebique system.

Concrete Shipbuilding in U.S.A.—The following are some extracts from the New York *Journal of Commerce* regarding the progress of concrete shipbuilding in America :—

Since the first commitment of the Shipping Administration to the policy of building concrete tonnage, plans have been pushed rapidly for the development of this type of ship. The confidence of officials in the practicability of the project is strongly reflected in a statement just issued by the Shipping Board, reviewing concrete shipbuilding activities and predicting success for the new vessels. The more important matter contained in this summary is presented as follows :—

" The construction of a total of forty-two new concrete ships has been authorised by the United States Shipping Board. Of these forty-two concrete ships, contracts for eighteen have already been given by the Emergency Fleet Corporation. Contracts for the building of the remainder will shortly be let. These forty-two concrete ships will nearly all be tankers of 7,500 tons each, with a capacity of 50,000 barrels of oil. Each of the 7,500-ton ships will have 2,800 horse power and a speed of 10½ knots an hour. Others of the concrete ships are cargo ships, of 3,000 and 3,500 tons. The forty-two concrete ships will have a total of 298,500 dead-weight tonnage.

" The five Government yards for the building of concrete ships are to be located at various points on our coasts. . . . There are also two private concrete shipbuilding yards. . . .

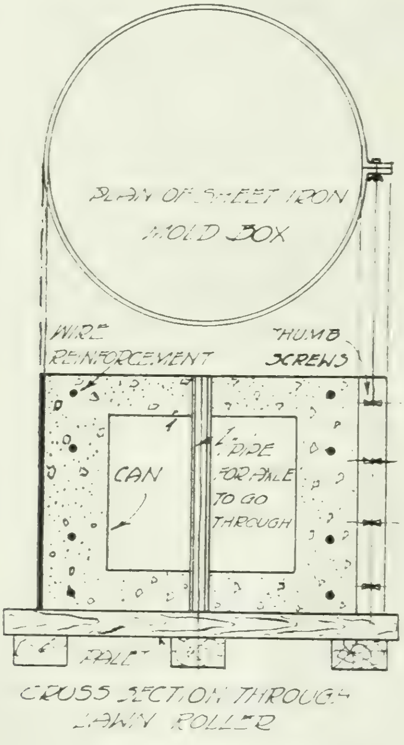
" ' When concrete ship building is well organised,' said Mr. R. J. Wig, head of the Department of Concrete Ship Construction of the Emergency Fleet Corporation, ' the only limit on the capacity to produce concrete ships will be the limit of the machinery and equipment for the construction of the ships. . . .'

" To organise concrete ship plants is an easy and inexpensive matter compared with the intricate arrangements necessary for steel ship construction.

" All that is needed for concrete ship construction is a simple plant. This is made up of concrete mixers, hoists and other plain equipment which is obtainable in any large city. Such a plant can be rapidly put together and in speedy working order. Ways similar to those used for wood and steel ships must, however, be provided. . . .

"The great value of concrete ships is recognised in other countries. A 2,500-ton concrete ship has been launched at Tientsin, China, and a 2,200-ton concrete ship will be launched in August, 1918, at Saigon, French Indo-China. Recently a small concrete ship was launched at Montreal. Concrete vessels are also under construction in Spain, Italy, Norway, Denmark, and Germany. . . ."

Concrete Ships for Africa.—In view of the prospects of concrete ships in the near future, it is of interest to know that one or two yards in this country are setting themselves out to supply barges and other craft, constructed of concrete, suitable for use in African waters. The climatic conditions on the West Coast are not favourable either for wood or steel lighters, the former being subject to the Toreda worm, and the steel falls a victim to excessive corrosion which takes place with steel structures in that part of the world.—*African World.*



How the Roller is made

Concrete Water Meter Boxes.—The local authorities at Superior, Neb., have approved designs for concrete boxes for water meters, which take the form of a cylindrical concrete shell provided with attachments for covers.

A Hollow Concrete Lawn Roller.—The accompanying diagram shows how to make a hollow concrete lawn roller. The roller shown is 24 in. in diameter and 18 in. wide and weighs about 300 lb. The firm in Ohio making these rollers obtain empty oil and grease cans from local garages to form the core, thus lightening the roller and saving the concrete.—(From *Concrete,* U.S.A.)

Brush-Finishing Concrete Surfaces.—According to *Concrete,* U.S.A., a finish for concrete that will give a uniform and very satisfactory surface is produced with a whitewash brush as the finishing tool.

Remove the forms at the earliest possible time ; paint the surface with a grout of (1) lime, (2) cement, and (3) fine sand, mixed with water to a creamy consistency and kept thoroughly stirred.

Follow the application of the mixture with a thorough rubbing of the surface with a wood float to fill thoroughly all pin holes and produce an even texture.

As the excess moisture disappears brush the surface lightly in both directions with a dry brush to obliterate all float marks and produce a sandpaper-like texture. The surface thus treated will be very light in colour and the effect is permanent under most conditions.

The Use of Concrete in Road Construction.—In view of the decision of the South Australian commissioner of crown lands (Hon. H. Jackson) to have experiments made on a section of the Bay Road, Adelaide, to ascertain the relative values of different metals and top dressings for bearing general traffic, it is interesting to note that Adelaide's first experimental roadway in reinforced concrete has withstood its tests satisfactorily. The Adelaide experiment in a concrete road surface was completed in November, 1915, in a 13-ft. right-of-way. It was laid down on the American standard for a distance of two chains. It has had to cope with the concentrated heavy traffic of lorries laden with all kinds of ironwork and machinery, under which the ordinary macadam very soon went to pieces. The new road was made with a foundation course of 6-in. cement concrete, on top of which was laid a triangle-mesh steel reinforcement, and it was surfaced with an inch and a half of cement composition as a wearing coat. No asphalt or tar was put on. About four months ago Mr. J. R. Richardson, city engineer, found the roadway beginning to show slight signs of wear, after having stood remarkably well for two years, and it has since been given a good dressing of bituminous asphalte.

Oil Storage Tanks.—In Bulletin 155 of the U.S.A. Bureau of Mines, Mr. C. P. Bowie gives the result of some investigations made by him into oil storage tanks and reservoirs. The losses of oil in storage and methods of prevention of losses are also discussed. Mr. Bowie's investigations have shown that tanks composed wholly of steel give the best results. Where larger containers than it is feasible to build with steel are desired, concrete-lined reservoirs can be recommended for some grades of oil. Practically all such containers in use at present have wooden roofs, but it is Mr. Bowie's belief that concrete roofs would be far more satisfactory in every way, and that the difference in cost between a concrete and a wooden roof would, as a rule, in a few years' time be offset by a saving of oil and in cost of repairs and renewals. Steel tanks for the storage of oil are manufactured in various sizes up to 55,000-barrel capacity. These have a diameter of 114 ft. 6 in., and are 30 ft. high. The usual size is the 55,000-barrel tank, although the Standard Oil Company, especially, is using great numbers of 37,000-barrel tanks.

In regard to concrete-lined reservoirs it is stated that where proper care has been taken to make a dense compact lining in which all coarse material is well embedded below the surface there seems no doubt that an oil-tight structure can be made. Mr. Bowie has repeatedly seen samples of concrete lining taken from the bottoms of reservoirs 20 ft. in depth which have been in use for a period of five years. These have shown practically no penetration whatever. Mr. H. B. Truett, chief engineer of the fuel-oil department of the Southern Pacific Railroad, states that he examined a 750,000-barrel reservoir belonging to the company after it had been in continuous use for several years, and found the concrete lining in practically perfect condition. A scratch with a penknife removed the oil from the surface of the lining and showed the concrete white and unattacked in almost every place examined, and he found numerous places where the oil could be wiped from the surface of the lining, leaving it scarcely discoloured and as smooth and firm as the day it was put in.

A properly constructed concrete-lined reservoir with concrete roof will last for an indefinite period. The life of the modern steel tank is variously estimated. The consensus of opinion among the majority of oil men seems to be that a commercial steel tank such as is in use to-day, if placed on a carefully constructed foundation, and if properly maintained, should last, with the exception of the roof, for thirty five to forty years. The roof, if of wood, covered with roofing paper, would, of course, require repeated repairs during this period to keep it waterproof, and, even though

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it were constructed of steel, parts of it might need to be replaced three or four times, by reason of deterioration from light hydrocarbon gases and sulphur fumes.

Several oil tanks examined by Mr. Bowie have been in use for twenty to twenty-five years, and their shells are to all appearances in almost perfect condition. One tank at the Standard Oil Company refinery, Baltimore, Md., of 30,000-barrel capacity, has been in continual service for more than thirty-five years. This is a wrought-iron tank made from plates much lighter than those used at the present time for a tank of this capacity. The rivet spacing is also greater than is used in modern practice, which means that the tank was not designed with what is considered to-day an adequate factor of safety. For this reason, for several years past it has been carried only about two-thirds full, and, so the superintendent states, will be cut down and replaced in the near future. The roof has been replaced several times, but the shell, so far as can be seen, is sound and in good condition.

The Shell Oil Company of California uses a gasholder for the collection of the light gases from the oil tanks. The gasholder is attached to a battery of storage tanks of gas-tight construction. Its purpose is to take care of the expansion and contraction, owing to changes in temperature, of the light gases filling the space between the surface of the gasoline and the tops of the tanks. If one tank in the battery is being filled while another is being emptied, the function of the holder is also to conserve the gases discharged from the tank being filled. Such gases ordinarily escape into the atmosphere, but the holder causes them to be returned to a tank being emptied. There seems no reason, says Mr. Bowie, why such a system could not be applied to run-down tanks, and the like, a provision being made whereby any surplus gases not taken care of by the holder could be drawn off and condensed, or otherwise profitably disposed of.

British Portland Cement.—From the annual report of the British Portland Cement Manufacturers, we learn that there was an active demand for cement during the past year, and notwithstanding the great difficulties connected with manufacturing operations and with the distribution of the finished product, particularly with regard to the scarcity of labour, the profits for the period show an improvement as compared with recent years. On April 4th last the Army Council required the whole production of cement in the United Kingdom to be placed at its disposal, and on May 11th prohibited the exportation of cement until further notice.

Permits for the Release of Cement.—The Secretary of the War Office announces that permits for the release of cement will be issued by the Director of Army Priority (D.A.P.3.C.), Caxton House, Tothill Street, S.W.1. Applications for permits should be made by the firm or persons requiring to use the cement and not by the manufacturer or merchant. The quantity required, the purpose for which it is required, and the name and address of suppliers must in every case be stated.

Londonderry Wharf Extension.—At the monthly meeting of the Londonderry Port and Harbour Commissioners, Mr. William Donnell, J.P., proposed that the Commissioners take into consideration the question of the extension of the wharf as far as the Boating Club, the extension to be carried out in reinforced concrete and project into the channel 50 ft. from the breast of the present wharf.

The Chairman seconded the resolution, which was passed, and the Engineer was asked to submit plans which had been previously prepared in connection with the scheme.—*Lloyd's List.*

Exhibition of Designs of Workmen's Dwellings.—Industrial dwellings of the "model city" at Morgan Park, Minn., were a feature of an architectural exhibit at the Art Institute, Chicago, one room being devoted to a display of plans, photographs and paintings of the town and its buildings. This town was established a few years ago by the Minnesota Steel Co. to provide accommodation for employees at its large steel plant near Duluth. The buildings are of concrete block construction and range from single residences to long structures forming three or four residences. Wide streets with a curved layout and ample provision for gardens, playgrounds and other open spaces are characteristics of the general plan. The designs were made by Dean & Dean, of Chicago, architects for the Morgan Park Company.

Concrete Machine Tools.—The necessity for building machines for the construction of very large guns has brought about an important development in mechanical engineering, and concrete is now playing an important part in large machine-tool building. To build gun-boring machines which require very long ways it is necessary to have planing machines of exceptional length. In a Chicago shop recently two big planers have been built of concrete, instead of metal. They are, of course, provided with metal surfaces where finished parts are needed, but the bed of the planer and the platen, as well as the housing and cross-rail, are of concrete. The bed is 148 ft. in length, and the platen 92 ft. long. This latter is 13 in. in thickness and the concrete cross-rail is 4 ft. square. The top of the housing is 9 ft. 6 in. above the bed. Altogether the planer contains 13,500 cu. ft. of concrete and 34,000 lb. of reinforcing steel. The total weight of each machine is 1,600,000 lb. The time of building, from the laying of the foundations to setting the machines to work, was eleven weeks, the work being carried on night and day without a stop.

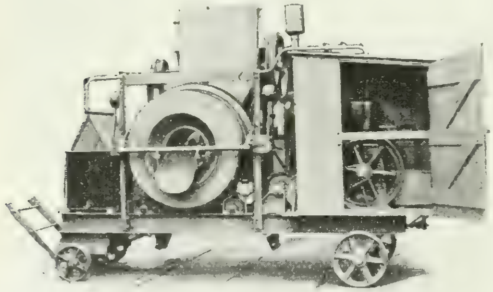
TRADE NOTES, CATALOGUES, ETC.

The British Steel Piling Co., of Dock House, Billiter Street, London, E.C.3, have just issued two new catalogues, one dealing with their " Zenith " Steam Friction Winches and the other describing briefly their " Atlas " Ball Bearing Jacks. Copies of these catalogues will be sent to anyone applying to the company at their address given above.

Messrs. Barimar, Ltd., of 10 Poland Street, Oxford Street, London, W.1, call attention to the fact that they can make repairs promptly to motor lorries at a cost not exceeding £20, and to motor vans, cars and motor cycles not exceeding £10, without Priority certificates, provided the orders be accompanied by declarations as to the uses to which the vehicles are put. Where the costs exceed these figures, applications for permission to order repairs should be sent to the Ministry of Munitions, Priority Branch, Caxton House, Westminster, S.W.1.

PUBLICATIONS RECEIVED.

Selwyn's Metric Tables. Published by Jas. Selwyn Co., Ltd., 20, Essex Street, Strand, W.C.2. (Price 2s. 6d. nett.)



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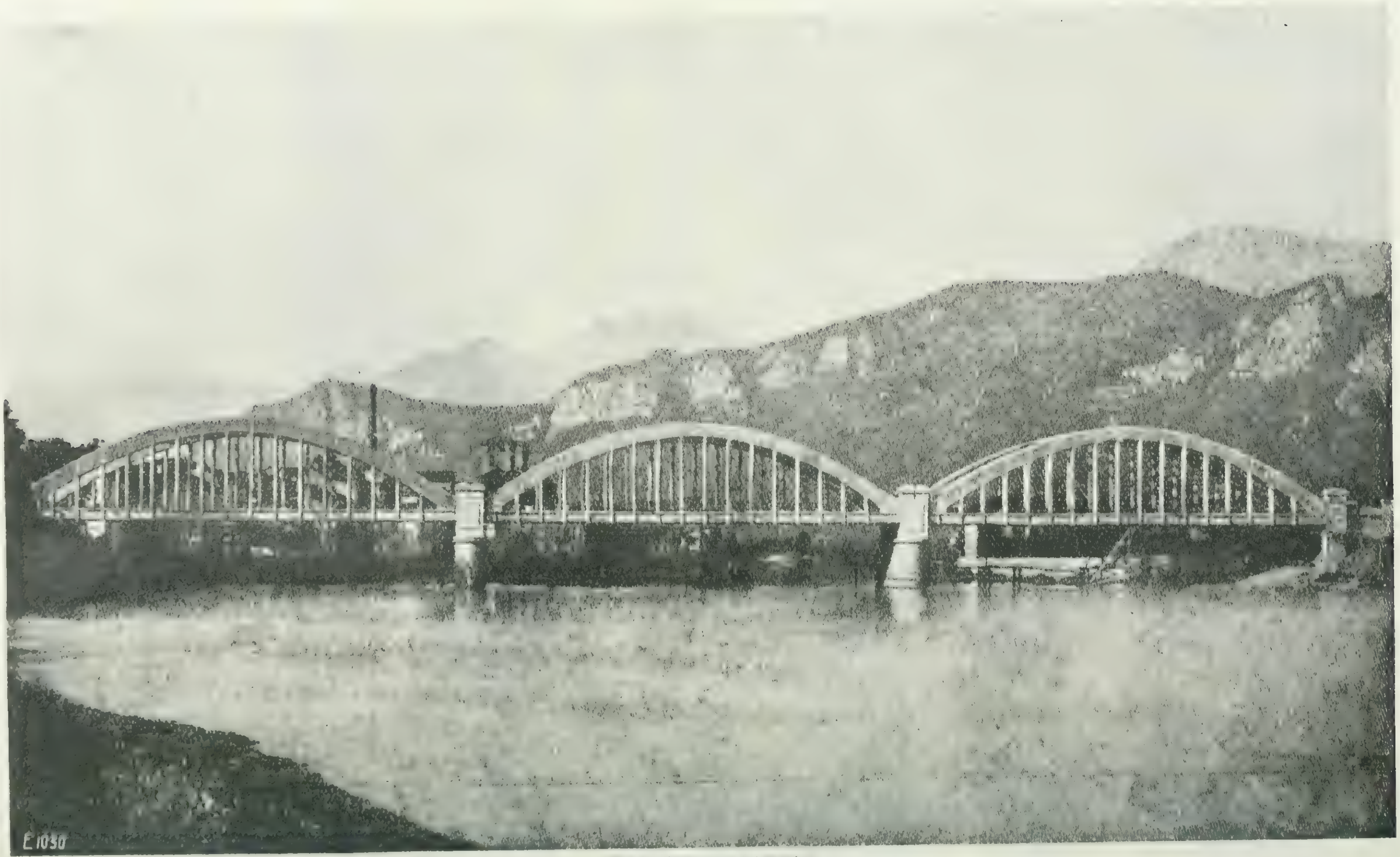


View of Completed Bridge.
Concrete Bridge in Italy on the River Adda at Brivio.
(For Description see page 468.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIII., No. 9. LONDON, SEPTEMBER, 1918.

EDITORIAL NOTES.

THE CORRECT PROPORTIONING OF CONCRETE.

THE article describing the tests which were undertaken by Messrs. H. C. Johnson and W. Kingston, on page 453 of this issue, while not altogether convincing to the practical man, contains a great deal of interesting matter, and it indicates a certain amount of progression which is commendable. We feel, however, that the results and comments are not such as will lead to the abandonment of the 1 : 2 : 4 method of specifying a concrete mix, and while it is perfectly clear that this existing method is not strictly scientific it is eminently practical, and some very conclusive arguments will be necessary before a less practical though more scientific specification is adopted.

WATER PLAYS AN IMPORTANT PART.

Exhaustive tests and investigations as to the ideal proportions for all classes of concrete are absolutely essential, and such tests should certainly form part of the programme of the institute which is devoted to the advancement of the use of concrete. but there are certain points which must not be overlooked if the results are to be absolutely reliable. One of the chief of these is the fact that the amount of water used plays a very important part in the strength of the resulting concrete, and in our last issue we published an article by Professor Duff A. Abrams, which showed in a striking manner that as long as a workable mix was obtained then the less the water used the greater the streng thof the concrete.

Now it is interesting to note in the table prepared by Messrs . Johnson and Kingston that in every case the strongest concrete is that mixed with the smallest percentage of water, regardless of the proportions of the cement and aggregate, or whether it was a 1 : 2 : 4 mixture or a " corrected " mixture ! In the face of this fact one is rather tempted to consider whether the 1 : 2 : 4 mixture might not have proved the stronger mixture of the two in every case if the percentage of water had been reduced to a little below that used for the corrected mixture. It is certainly curious that the results should be affected in this way, and a good case can scarcely be made out for " corrected " concrete unless an increased percentage of strength for the cement used is supported by the fact that the same amount of water was used as that employed for the mixture under comparison. It will also be seen in some examples that the 1 : 2 : 4 mixture was not only stronger but that the corrected concrete showed a percentage decrease in strength. As the values given are average ones it shows that the corrected concrete is not absolutely dependable although based on scientific methods, and, furthermore, the results given seem to show a greater variation than with the practical method. There are other curious features that will be noticed—viz., that the heaviest concrete was produced with a 1 : 2 : 4 mix made up with broken limestone and coarse sand, and yet at the age of three months the concrete gave the lowest value as regards strength of all the 1 : 2 : 4 mixtures ! Here is another aspect which must not be lost sight of in connection with these tests, and that is whether the small difference in the percentage of cement between the two classes of mixtures is sufficient to make any real difference in practice.

PERCENTAGE OF CEMENT.

It will be noticed that the difference in the percentage varies from about 3 to ·05, and unless some method of measuring the cement in the actual work was adopted which was fool-proof or in some way automatic we are afraid that the variation due to the uncertainties of the human element which enter into the gauging even with accurate gauge boxes will result in a percentage variation of often more than 1 per cent. It is true that where efficient supervision is employed concrete mixtures can be turned out of a uniform nature, but the supervisor cannot stand at the mixer all the time, and by reducing the amount of cement we are allowing a smaller margin for waste, negligence, or indifference. The only two factors which set up a chemical action in the mixed concrete to give a solid material are the cement and the water, and of these one is the most expensive factor to the contractor and the other is the cheapest. Now we do not desire to see cement wasted, but it is certainly necessary to ensure sufficient being used, and there must be some margin for the human element as abovementioned.

These practical points do not, of course, in any way detract from the value of any results that may be obtained from a scientific point of view, but they should not be lost sight of when it comes to the practical application of such results. If a stronger concrete can be produced with less cement it is the duty of every engineer to protect his client's interests by seeing that he gets the benefit of the saving in cost, and the better material, but he must not run any risks in achieving this result.

GRAVEL AND BROKEN STONE AGGREGATE.

With regard to the comparisons which are made in the article between gravel and broken stone as an aggregate, we feel that the reasons put forward for the rejection of gravel by many people do not quite hold good. In actual practice many engineers find it difficult to obtain such a good surface finish with concrete made with uncrushed gravel, as groups of round stones will appear in patches on the face of the work when the shuttering is removed. This is generally caused by the natural tendency of the smooth round stones to run together when the concrete is placed in the form, and as the centre of the concrete so often rises slightly above the sides during the actual depositing these stones run down toward the face of the forms, and it involves exceptional tamping to prevent these patches, which are often nearly devoid of cement, from occurring. The same thing occurs at the construction seams caused by the junction of new work with old, as there is not the interlocking tendency to resist the downward movement of the heavy particles as there is with broken stone, and the rough surface of the latter also gives greater frictional resistance to such movement. This condition is aggravated in the case of gravel when the mixture is mixed with a large percentage of water, which makes the concrete liquid to flow around reinforcement. Several instances of the kind have recently been observed, and the results have led architects and engineers to adopt broken stone in preference to gravel.

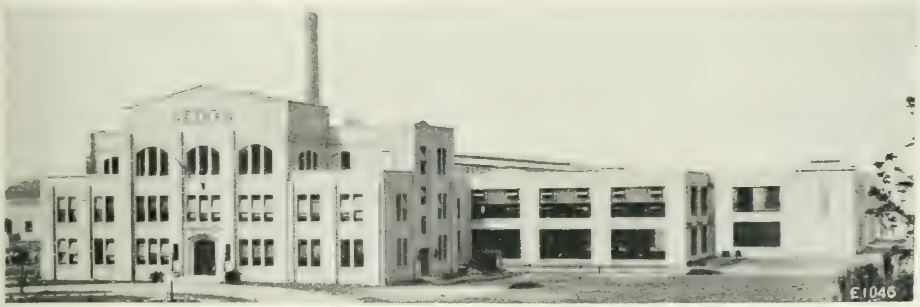
IMPORTANCE OF RESEARCH.

There is a great deal to be done in the investigation of the best proportion and method of mixing for concrete, and it needs a few pioneers, such as Messrs. Johnson and Kingston, to create a lively interest in such matters and make engineers generally realise the importance of the subject, and although our remarks may appear to be critical in some instances we must plead that we, too, are pioneers who have endeavoured to stimulate progress in good concrete work, and as such we criticise in order to assist.

In conclusion, it is highly important, in our opinion, that a part of the research work undertaken in the immediate future should include comprehensive tests of concretes made with all the different classes of aggregates to determine (*a*) the effect of the percentage of water used in relation to the measure or weight of the dry materials ; (*b*) the minimum amount of cement that should be employed with the various aggregates to give concrete having specified minimum strengths ;

and (*c*) the best proportions for coarse aggregate, fine aggregate, cement, and water for different materials with the manner of specifying these, and, if possible, some practical recommendations, for the benefit of the person responsible for the work, as to how the gauging and mixing should be done to ensure the specification being complied with.

When this has been achieved we feel that a real step forward will have been made in the direction of the manufacture of concrete in conformity with scientific methods on practical lines.



General View of Factory.

THE NEW PREMISES OF THE NATHAN MANUFACTURING CO., FLUSHING, LONG ISLAND.

By ERNEST G. W. SOUSTER, A.R.I.B.A.

The statement that everything except human nature will have changed by the time that the war is finished is now becoming a trite remark, and although the characteristic conservatism of the average Briton may be relied upon to favour a *status quo* attitude and to act as a brake upon enthusiasts of change, there is no doubt that the point of view from which factory design is and will be in the future approached differs materially from that in vogue previous to 1914.

It must, of course, be admitted that some firms were far-seeing enough to realise that the newer ideals of factory design as exemplified by many American corporations would in the end tend to greater productivity and a raising of the self-respect of the worker, with a consequent humanisation of the whole of the works, but, generally speaking, the legacy of mid-Victorian industrialism still held sway.

The coming of the war and the necessity of increasing output and conserving the strength and vitality of the workers has led to searching analyses of every department of industrial life and has caused us to examine and endeavour to surpass what has been done in America, where the *ensemble* of factory design has been raised to a science, and we have therefore great pleasure in illustrating the premises of the Nathan Manufacturing Co., of Flushing, Long Island, New York.

As will be seen from the general plan, the site of the works is somewhat irregular, but is bounded on three sides by streets, whilst the rear abuts upon a canal, thus giving facilities for water-borne traffic.

The main block of the buildings is set back a good distance from the public roadway and is approached by a drive bordered on either side with grass and trees.

The administrative block, placed axially to the drive, occupies the front of the mainblock, and continuing this axis a gangway (see *Figs.* 1 & 5) runs from rear of this building through the whole structure. This gangway, which is 26 ft. wide and 34 ft. high to springing of beams carrying roof, is top lighted and has two travelling cranes of 7 tons capacity running from end to end ; the runner for them being supported by reinforced concrete corbels projecting from each main pier. From this gangway access is gained to each of the six departments of the works, which are placed at right angles to it and at distances of 40 ft. apart (see *Figs.* 1 & 2). All these structures are built on a unit system of 25 ft. by 20 ft., thus giving a width of about 60 ft. to each building.

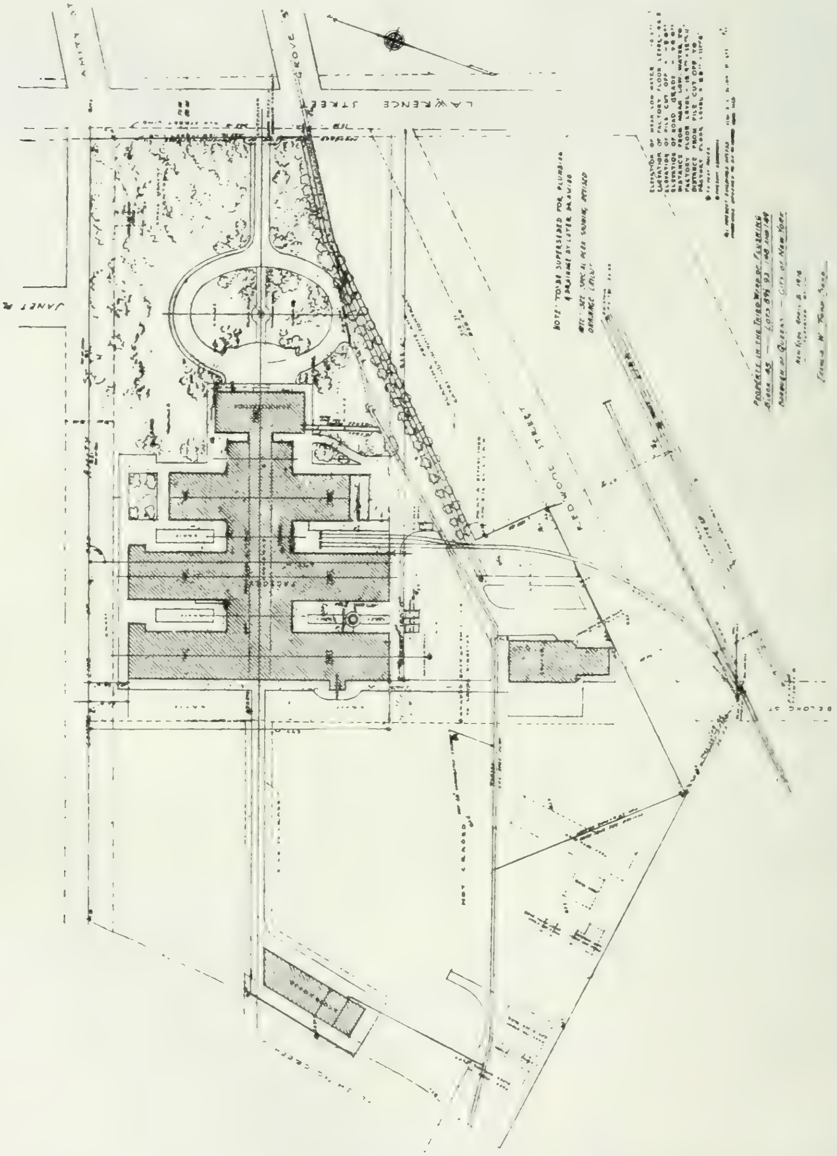


Fig. 1. General Site Plan.

Factory for the Nathan Manufacturing Co., Flushing, Long Island, New York.

Bridges across gangway connect the upper floors, and between the blocks and on either side of the gangway four groups of conveniences, locker rooms and staircases have been arranged. This concentration of all sanitary conveniences leaves clear rectangular working spaces, and, to prevent unnecessary interruption in the works, drinking fountains have been placed in convenient positions throughout the buildings.

The administrative block (see *Fig.* 3) is three stories in height. The ground floor is occupied by general offices and work-rooms, the first floor by executives and directors, and the second floor serves as separate dining-rooms for both chiefs and staffs, kitchen department and rest-rooms.

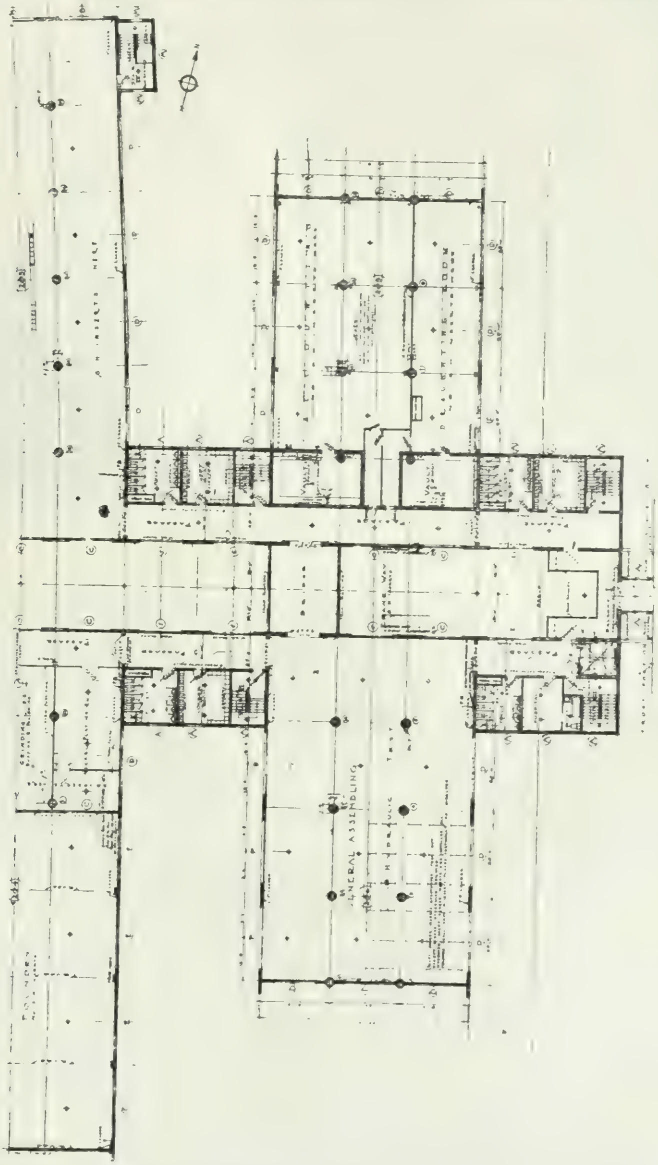


Fig. 2. Second Floor Plan.

Factory for the Nathan Manufacturing Co., Flushing, Long Island, New York.

At the rear of the administrative building and from each of the upper floors of it access is obtained to galleries overlooking the gangway, and passages therefrom allow any portion of works to be easily reached (see *Fig.* 5).

CONSTRUCTION.

The site of the factory being on marshy, low-lying land, certain difficulties were met with in the design of the foundations, and borings having proved that a spread foundation was inadequate, timber piles varying from 30 to 60 ft. were driven. On these piles 12 in. concrete slabs were placed and the entire footing formed upon them.

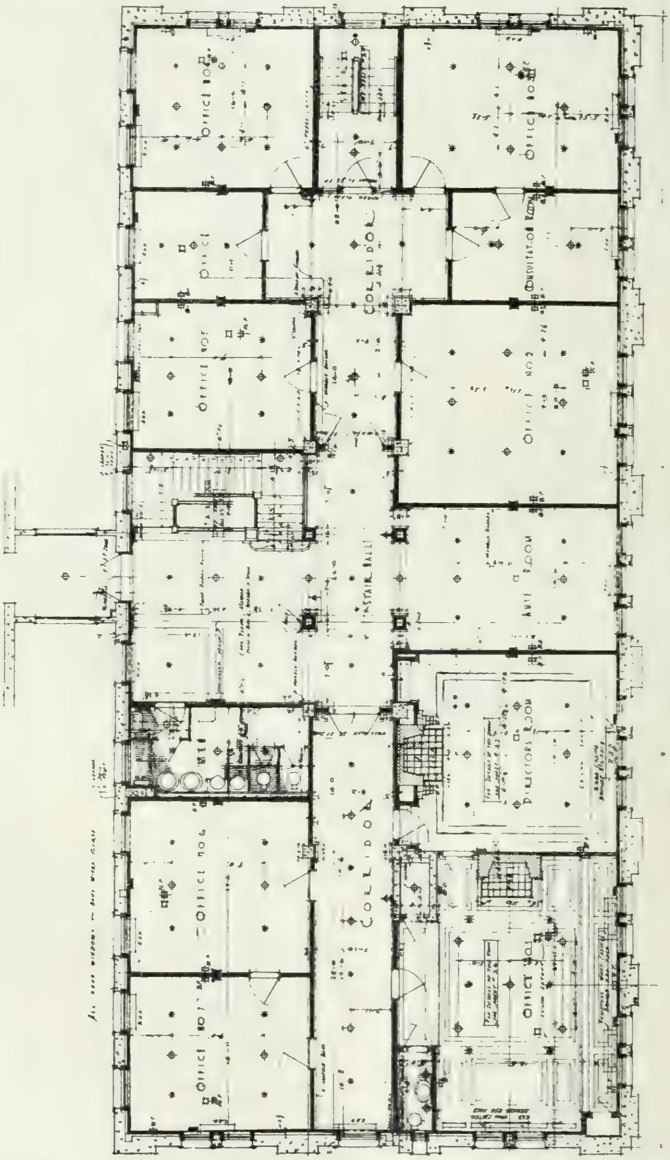


Fig. 3. Administration Building First Floor Plan.
Factory for the Nathan Manufacturing Co., Flushing, Long Island, New York.

The ground floor consists of a beam and concrete arched slab and was formed by constructing the beams with notch to receive the concrete arch. Hy-rib was then placed between beams and concrete poured to the finished surface. The

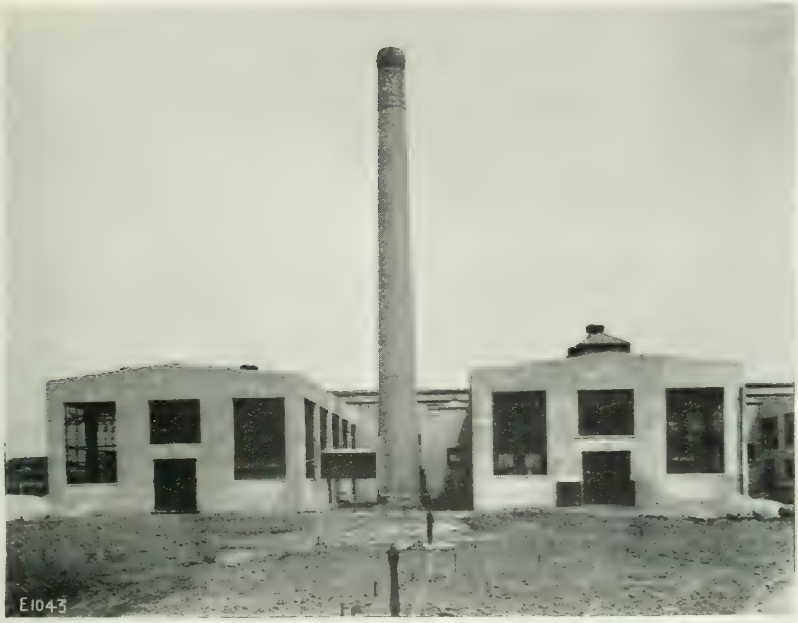


Fig. 4. Foundry and Power House.

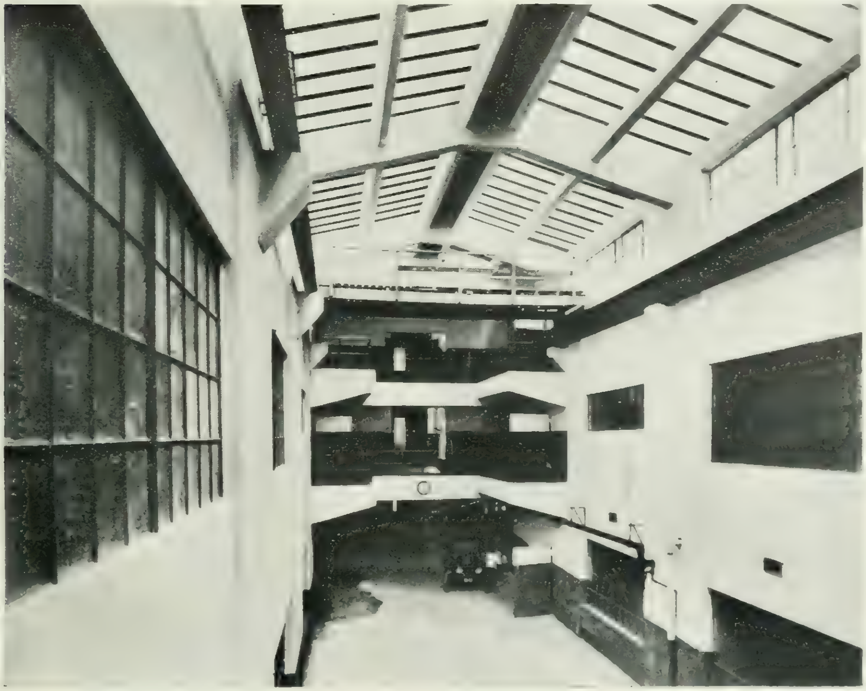


Fig. 5. Gangway through Works.
FACTORY FOR THE NATHAN MANUFACTURING CO., FLUSHING, LONG ISLAND, NEW YORK.

necessary service pipes were hung from these beams by means of hangers placed in position before the arch was formed.

The first floor and roof consist of flat slabs with mushroom supports over the piers, but in the foundry and power house, where internal columns are omitted, steel trusses resting at ends on reinforced concrete piers span the whole building and carry a reinforced concrete roof slab.

The construction of the administrative building is of reinforced concrete walls and columns and steel floors.

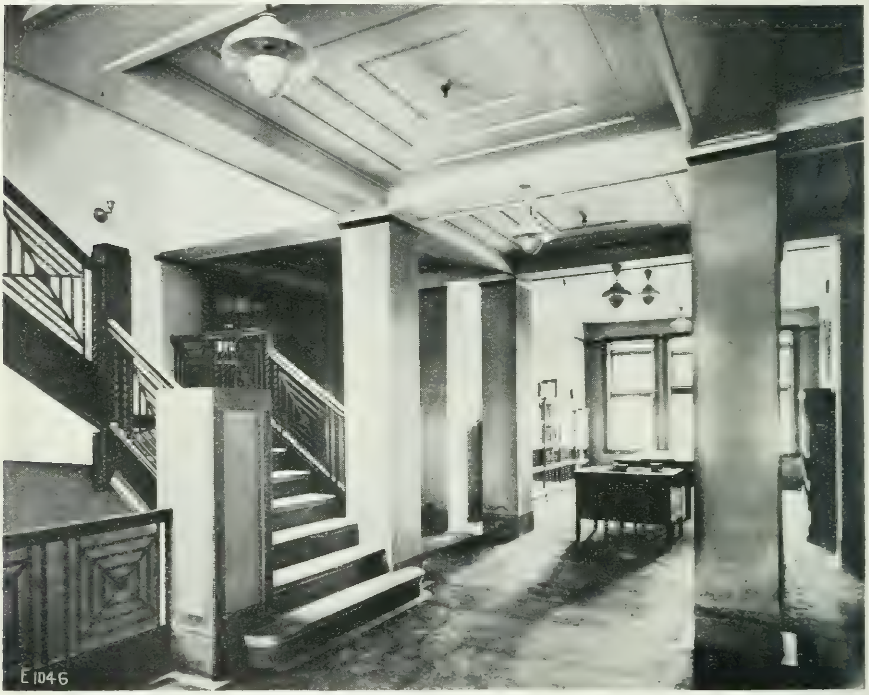


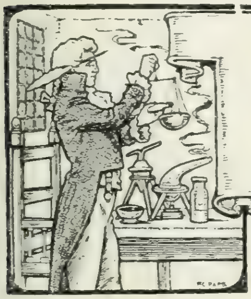
Fig. 6. Second Floor Hall and Library—Administration Building.
FACTORY FOR THE NATHAN MANUFACTURING CO., FLUSHING, LONG ISLAND, NEW YORK.

Throughout the building both horizontal and vertical pipe ducts have been formed and shaft hangers built into ceilings and columns so that machines may be moved as required.

During the progress of the work the concrete was mixed and distributed by means of a platform fixed on the piles prepared for one of the sanitary blocks, and this occupied a relatively central position in the structure.

A tower, 130 ft. high, was built here and the concrete distributed to the positions required by means of chutes, and where this was impossible buggies received the mixture from chutes and carried it to its destination.

The architect for the works was Mr. Eugen Schoen, of 112, East Nineteenth Street, New York, the consultant engineer being Mr. Isador Fried, and to these gentlemen we are indebted for the information contained in this article and for the loan of the illustrations.



THE CORRECT PROPORTIONING OF CONCRETE.

By H C. JOHNSON and
W. KINGSTON, B.E. [University
College, Cork.]

The question of the correct proportioning of concrete is one that is receiving considerable attention at the moment and the results of the tests recently carried out at the Cork University will probably be of interest to our readers.—ED.

THE following series of tests was undertaken with a view to showing that the common practice of specifying for concrete such proportions as 1 : 2 : 4, 1 : 3 : 6, etc., is not practical and is unscientific, since it does not take into consideration the adaptability of the grading to the production of the best possible concrete with the given aggregates.

There are three facts about 1 : 2 : 4 concretes which suggested the lines on which one should aim at proportioning concrete :—

(1) The amount of cement in a finished volume of 1 : 2 : 4 concrete varies, with different aggregates, by as much as 30 per cent. This has originated the erroneous idea that gravel is not so good as stone as an aggregate, while the fact is that a greater volume of concrete is produced by using gravel. Hence gravel has often been rejected in favour of stone as an aggregate, when, if given an equal chance, it would have made an equally strong, more workable and more impervious concrete.

(2) The proportion of sand to large aggregate in 1 : 2 : 4 concrete is always the same no matter what kind the aggregate is. Now, tests have proved that the grading being satisfactory, the coarser the aggregate the stronger the concrete. The reason for this seems to be that the surface area of small aggregate is greater than that of large, and therefore more cement is needed in uniting these small particles (which are united in themselves in the large aggregate). Therefore, it seems unreasonable to introduce into a concrete more of this small aggregate than is absolutely necessary.

(3) 1 : 2 : 4, 1 : 2½ : 5 and similar concretes vary in density because no attempt is made to obtain a concrete of the greatest weight per cu. ft. for a given set of aggregates. The result of this is a weaker and more porous concrete, affording less protection to the steel in reinforced work.

From these facts it was decided to try to improve on the old method of proportioning by making concretes having :—

(1) Equal percentages of cement in the finished volume of concrete.

(2) Least possible amount of the small aggregate consistent with the production of a workable concrete.

(3) Greatest density.

This is called "corrected concrete," and, for comparison, a series of ordinary 1 : 2 : 4 concretes was made with the same aggregates.

From a previous series of experiments it was found that the *average* amount of cement in 1 : 2 : 4 concretes is about 21 per cent., which it was decided to use for all the "corrected concretes."

Sand is introduced into concrete to fill the voids in the large aggregate and to make the mixture workable. The voids in the large aggregate are just filled when the weight per cu. ft. of the concrete ceases to increase, and any more sand only spreads the mass and weakens the concrete, and is unnecessary provided the concrete is workable.

METHOD OF PROPORTIONING.

The method adopted in finding the correct proportions was therefore as follows :—

It is needless to say that previous knowledge of mixtures and the results to be expected are very necessary in arriving quickly at the correct proportions. The following table shows, step by step, the procedure adopted in finding the proportions for a 20% mix. It will be noted that the quantity of cement to be contained in 1 cu. ft. of finished concrete (20 per cent. of 1 cu.ft.) is introduced at the start and none added later, but in the case of the aggregates a smaller quantity than is required in the finished concrete is taken, and additions are made later as is thought necessary.

Take 1 cu. ft. pail and measure out 0·8 cu. ft. of gravel and 0·25 cu. ft. of sand. Weigh out 0·10 of 1 cu. ft. of cement, 10 lb. (reckoning cement = 100 lb. per cu. ft.). Mix in the usual way with water, and find volume and weight of resulting concrete. This will not produce 1 cu. ft., so turn out and add sand until a workable concrete is obtained, and if this does not fill the pail add large aggregate, mixing and measuring on each addition until the 1 cu. ft. is arrived at. We now have 1 cu. ft. of concrete containing exactly 20 per cent. cement, and having the smallest necessary amount of small aggregate.

EXAMPLE.

Gravel.	Sand.	Cement.	Vol.	Weight.	Wt. cu. ft.	Remarks.
cu ft.	cu. ft.	cu. ft.	cu. ft.	lb.	lb.	
0·4	0·125	0·1	0·435	62	144	Not workable, therefore add sand 0·025 cu. ft.
0·4	0·15	0·1	0·460	67	145½	Still unworkable, add sand 0·025 cu. ft.
0·4	0·175	0·1	0·488	71	145½	Workable, but not to volume, add gravel 0·025 cu. ft.
0·425	0·175	0·1	0·502	73½	146½	Correct.
4¼	1¾	1	are correct	proportions.		

GRANULOMETRIC ANALYSIS OF LARGE AGGREGATES.
PERCENTAGE BY VOLUME RETAINED ON SIEVES.

Sieves.	Youghal Gravel.	Inniscarra Sandstone.	Newbridge Gravel.	Cork Limestone.
¾ to ⅝	7	2·5	1·8	9
⅝ to ½	10	10	10	32
½ to ⅜	17	17	14	22
⅜ to ¼	42½	38·8	38	8
¼ to ⅛	35½	39·5	41	39
Total ...	112	107·8	104·8	110

GRANULOMETRIC ANALYSIS OF SMALL AGGREGATES.
PERCENTAGE BY VOLUME RETAINED ON SIEVES.

Sieves.	Wicklow Sand.	Leighton Buzzard Sand.
$\frac{1}{4}$ to $\frac{1}{8}$	0	0
$\frac{1}{8}$ to $\frac{1}{16}$	0	1
$\frac{1}{16}$ to $\frac{1}{32}$	0·3	14·3
$\frac{1}{32}$ to $\frac{1}{50}$	38	41·6
Passed $\frac{1}{50}$	62·5	45·8
Total ...	100·8	102·7

NOTE.—These percentages are based on the original volume of the aggregate. When separated into parts by the sieves the volume got by adding the parts is greater than the volume of the original aggregate, and the greater this volume the better the grading.

MATERIALS.

Large Aggregate. —The large aggregates used were :—

Youghal gravel (sandstone).
Inniscarra stone (sandstone).
Newbridge gravel (limestone).
Cork stone (limestone).

The Youghal gravel was taken from the beach at Youghal and passed through ¾-in. and held on ⅛-in. sieve. This is a well-graded gravel of old red sandstone.

The Inniscarra stone was taken from the crusher and screened on the ¾-in. and ⅛-in. sieves. This is a hard green sandstone which breaks with sharp angles.

The Newbridge gravel, as obtained from the pit at Newbridge, co. Kildare, is a uniform-sized black limestone almost all passing ¾-in. sieve.

The Cork stone was hand broken. It is a well-graded hard crystalline limestone (¾ in. to ⅛ in.).

The granulometric analysis of these are shown in the table.

Fine Aggregate.—The fine aggregate used was :—

Wicklow sand.
Leighton Buzzard sand.

The Wicklow sand was a very fine clean quartz sand.

Leighton Buzzard sand was the run of the pit, and medium sized. The granulometric analysis is given in the table.

Cement. —The cement used was a mixture of two brands :—

South Wales Portland cement.
Irish Portland cement (Magheramorne, co. Antrim).

In order that the mixture might be as uniform in quality as possible it was given 250 turns in the Olsen " Rattler " stone-testing machine.

The strengths of the separate and combined cements are as follows : –

—	Fineness.		Paste.		Mortar.		Per cent. Water.	
	76	180	7d	28d	7d	28d	Paste.	Mortar.
South Wales	0·2	7·47	650	715	364	430	21·25	8·33
Magheramorne... ...	0·21	8·67	470	620	233	400	22·4	8·5
Combined	—	—	545	670	286	417	—	—

Number of Test Specimens. —This gave four large aggregates, two sands and one cement, from which eight batches of " corrected " and eight batches of 1 : 2 : 4 concretes were made, each batch consisting of six 6-in. cubes and six cubes of 10 sq. in. face, giving 198 specimens.

MIXING.

The concrete was mixed in a Ransome batch mixer. The weight per cu. ft. of all materials was first found, and all volumes were then measured by their corresponding weights to eliminate the errors of volume measurement. All the aggregates necessary for a batch were placed beside the mixer, and the mixer was then started. The large aggregate was put in, and 10 lb. of water was added, and afterwards the sand and cement. Additional water was then added, and after five minutes the batch was discharged into a pan. A little more water was put in to clear the mixer, and after a few turns was discharged into a pail. Some of this was put into each mould to get a better surface on the specimen, and the concrete was then scooped in. The concrete was of such a consistency that very little ramming was necessary to bring water to the surface. The trowel was inserted between the concrete and the face of the mould to bring the finer material to the face of the specimen. The finished volume of the concrete and the weight of water used were ascertained, and careful note was taken of all operations. The following is an exact copy of an entry in the book during one operation :—

"Batch B1 ... ... Newbridge gravel.
4 : 2 : 1 concrete with fine sand.

Quantities required :—
Gravel, 73 lb. 11½ oz. (0·76 cu. ft.).
Sand, 35 lb. ¾ oz. (0·38 cu. ft.).
Cement, 19 lb. 0 oz. (0·19 cu. ft.).

The mixer was started at 11.40, and the gravel and water were put in. The sand and cement were introduced at 11.41, and additional water was then added to bring to the proper consistency. The mixer was discharged at 11.46. The mix was fairly wet, and very easily worked.

Finished vol. ... ... 0·87 cu. ft.
Water used ... ... 12·33 lb."

CURING OF SPECIMENS.

The specimens were allowed to remain in the moulds for 48 hours, after which they were taken out and immersed, two deep, in water in a large tank, where they remained for seven days. They were then taken out and laid singly on the floor of the laboratory so that five faces of each cube were exposed to the air. This procedure is quite essential to secure uniformity in the shape and condition of the specimens.

TESTING.

When the specimens were to be tested each cube was measured and weighed. It was then found that the faces of the 6-in. cubes, cast in wooden moulds, were not quite flat, so that it was necessary to grind down the surface by constant rubbing on the floor until a true face was obtained. The cubes were then placed, without packing, on a spherical seat in the 200,000-lb. Olsen testing machine and tested to ultimate load.

RESULT OF TESTS.					ONE MONTH			THREE MONTHS		
Proportions.	Materials.	Percentage cement.	Percentage of water.	Weight per cu. ft.	Strength lb. per sq. in.	Percentage increase.	Per cent. inc. per 1 per cent. cement.	Strength lb. per sq. in.	Percentage increase.	Per cent. inc. per 1 per cent. cement.
1 : 2 : 4	Sandstone gravel and fine sand.	21·6	9·4	143½	2,400	—	*	3,560	—	—
1 : 1·43 : 4·5		20·8	9·2	146	2,575	7·2	11·43	3,375	6·4	9·48
1 : 2 : 4	Sandstone gravel and coarse sand.	20·45	9·2	146	2,640	—	—	3,255	—	—
1 : 1·43 : 4·3		20·4	9·7	145½	2,292	13·2 dec.	13 dec.	2,970	8·75 dec.	8·54 dec.
1 : 2 : 4	Limestone gravel and fine sand	21·85	9·6	142½	2,320	—	—	3,645	—	—
1 : 1·43 : 4·3		20·90	9·3	145	2,890	24·56	30·2	4,020	10·28	15·3
1 : 2 : 4	Limestone gravel and coarse sand.	21·35	11·3	144	2,675	—	—	3,165	—	—
1 : 1·6 : 4·15		21	9·7	146	3,060	14·3	16·3	3,970	25·4	27·5
1 : 2 : 4	Crushed sandstone and fine sand	23·9	11·4	144	2,380	—	—	3,185	—	—
1 : 1·4 : 4·6		20·8	10·3	146½	2,750	15·5	32·7	3,355	5·3	21
1 : 2 : 4	Crushed sandstone and coarse sand.	21·5	9·7	146½	2,920	—	—	3,718	—	—
1 : 1·8 : 4·4		21·75	11	146	2,730	6·5 dec.	7·6 dec.	3,650	1·8 dec.	3·34 dec.
1 : 2 : 4	Broken limestone and fine sand.	23·35	10	147½	2,450	—	—	3,110	—	—
1 : 1·72 : 4·75		21	9·7	148½	2,710	10·6	22·85	3,660	17·6	30·9
1 : 2 : 4	Broken limestone and coarse sand.	22·25	9·7	149	2,535		—	3,103	—	—
1 : 1·67 : 4·5		21	9·8	148⅓	2,490	1·77 dec.	4·03	3,213	3·54	9·7

The above strengths are average values. The percentage of water is the percentage by weight of all dry materials.

* The difference per 1 per cent. cement is got by dividing the strength per sq. in. by the percentage of cement in the concrete and basing percentage difference on this.

CONCLUSIONS.

(1) Arbitrary proportions, such as 1 : 2 : 4, 1 : 3 : 6, should not be used in specifying for concrete.

(2) The quantity of cement should be based on the finished volume of concrete, and be defined as a certain percentage of this.

(3) The aggregates should be tested to find the proportions that will produce the best possible concrete with the specified percentage of cement.

(4) Gravel is as good an aggregate for concrete as stone, if not better, because it requires less sand to make it workable.

(5) In so-called 1 : 2 : 4 concretes lower strength is got with the finer small aggregate.

(6) In concrete proportioned as described, the size of the small aggregate does not make such a difference because less of the finer sand can be used.

(7) In all cases concrete containing the same aggregates gives increase of strength with increase of density.

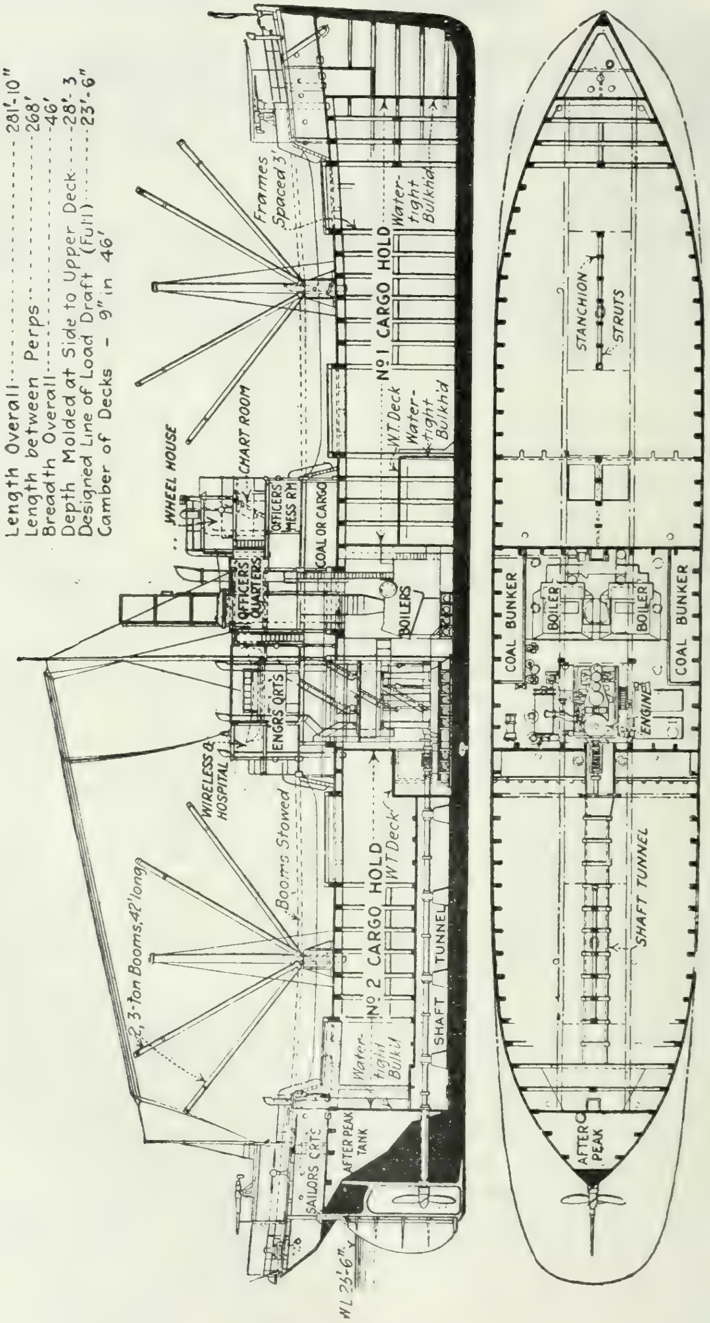
REINFORCED CONCRETE SHIPS IN U.S.A.

The following article and illustrations, reproduced from "Engineering News-Record," indicates the design followed by the American Government in the construction of their Concrete Ships. The shape and size are in accordance with the Standard wooden ship of the same tonnage.—ED.

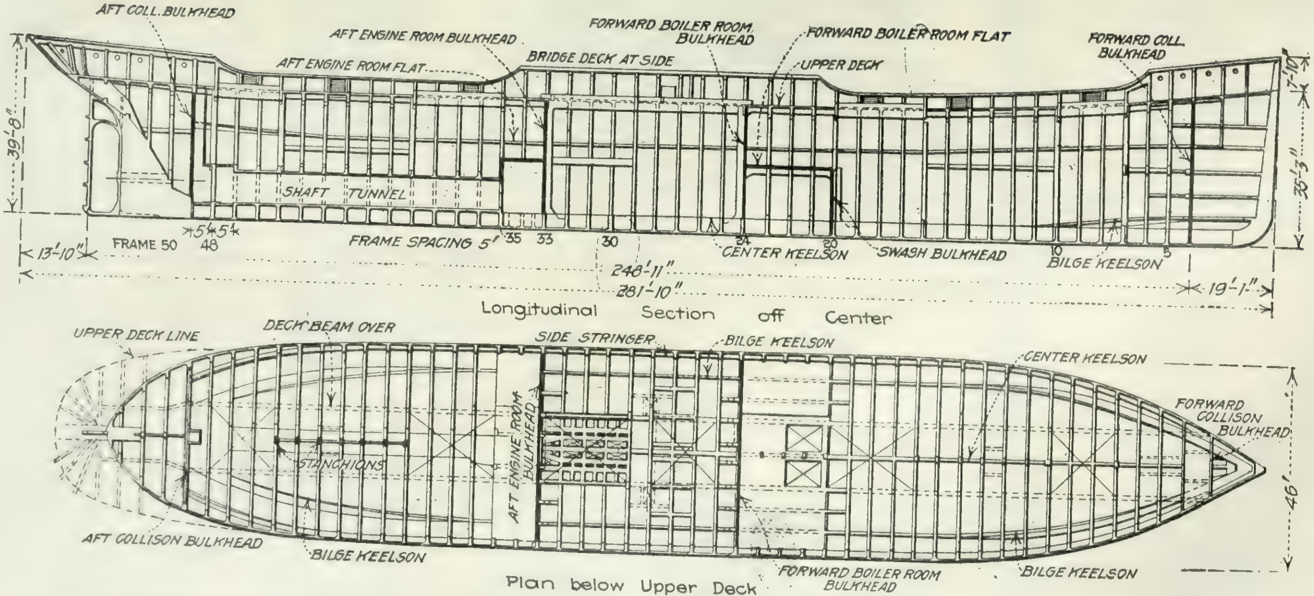
CONCRETE ship construction is now being undertaken by the United States Government on a large scale. Vessels of approximately 3,000-ton, 3,500-ton and 7,500-ton cargo carrying capacity have already been contracted for, and construction on the smallest of the three types, designed by the contractors under Government supervision, has been commenced in two yards. The concrete ship department of the United States Shipping Board, Emergency Fleet Corporation, of which R. J. Wig is chief engineer, has also prepared the design for the 3,500-ton ship, of which two are to be built.

To utilise the already designed and partly manufactured engines and fittings for the Fleet Corporation's standard wooden ships, the first standard concrete ship was made of approximately the same capacity, dimensions and form, except that the sheer line amidships of the concrete ship has been slightly altered and no exterior keel is fitted. The general arrangement of the ship itself and of the propelling machinery is the same in both types. As shown in one of the drawings, the ship is of single deck over its full section, with a poop deck at the stern, a forecastle deck at the bow, and a bridge deck, with a wood frame cabin house amidships. A single screw turned by a 1,400 h.p. reciprocating engine located amidships will give a speed of approximately 10½ knots. The boilers may burn either coal or oil.

The ship has a length over all of 281 ft. 10 in., a length between perpendiculars of 268 ft., beam over shell of 46 ft., depth amidships at sides of 28 ft. 3 in., and a loaded draft of 23½ ft. As shown in Table I., giving the comparative weights of concrete, wood and steel vessels of the same type, the concrete ship light weighs 2,972 tons, having a carrying capacity of 3,203 tons, and a full-load displacement of 6,175 tons. It compares closely in these dimensions with the similar wooden ship of somewhat larger dead-weight carrying capacity, but, as will be noted from the table, it is nearly twice as heavy empty as a steel ship, similarly rated, which has a carrying capacity 10 per cent. greater. Estimates of cost by the Shipping Board are between $100 and $125 per ton for concrete ship dead-weight carrying capacity as against $165 for wooden ships, and $180 to $220 for steel ships.



American Concrete Ship Design.



Longitudinal Section off Center

Plan below Upper Deck

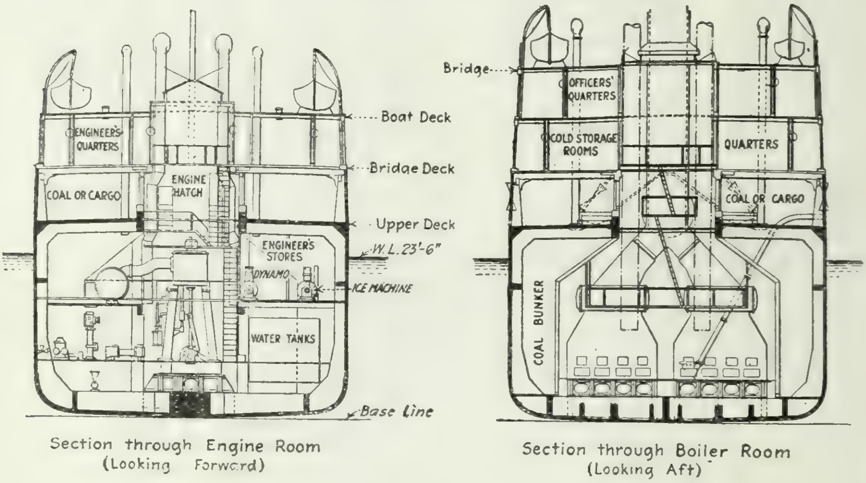
CONCRETE FRAMING IN 3500-TON CONCRETE SHIP. ADAPTATION OF SIMPLE BEAM AND SLAB DESIGN

American Concrete Ship Design.

TABLE I.

Comparative Weights of Concrete, Wood and Steel Vessels of Nominal 3,500-ton Dead Weight Capacity.

	Concrete.	Wood.	Steel.
Hull	2,500	2.300	1,160
Fittings, outfit, and equipment	191	191	180
Propelling machinery	206	206	200
Margin	75	80	60
Ship (light)	2,972	2,777	1,600
Reserve feed	80	80	80
Ordnance	23	23	23
Fuel	300	300	300
Stores	40	40	40
Cargo	2,760	2,180	3,057
Total dead weight	3,203	3,123	3,500
Full-load displacement	6,175	5,900	5,100
Percentage dead weight to full-load displacement	52	53	68·6



Section through Engine Room (Looking Forward)

Section through Boiler Room (Looking Aft)

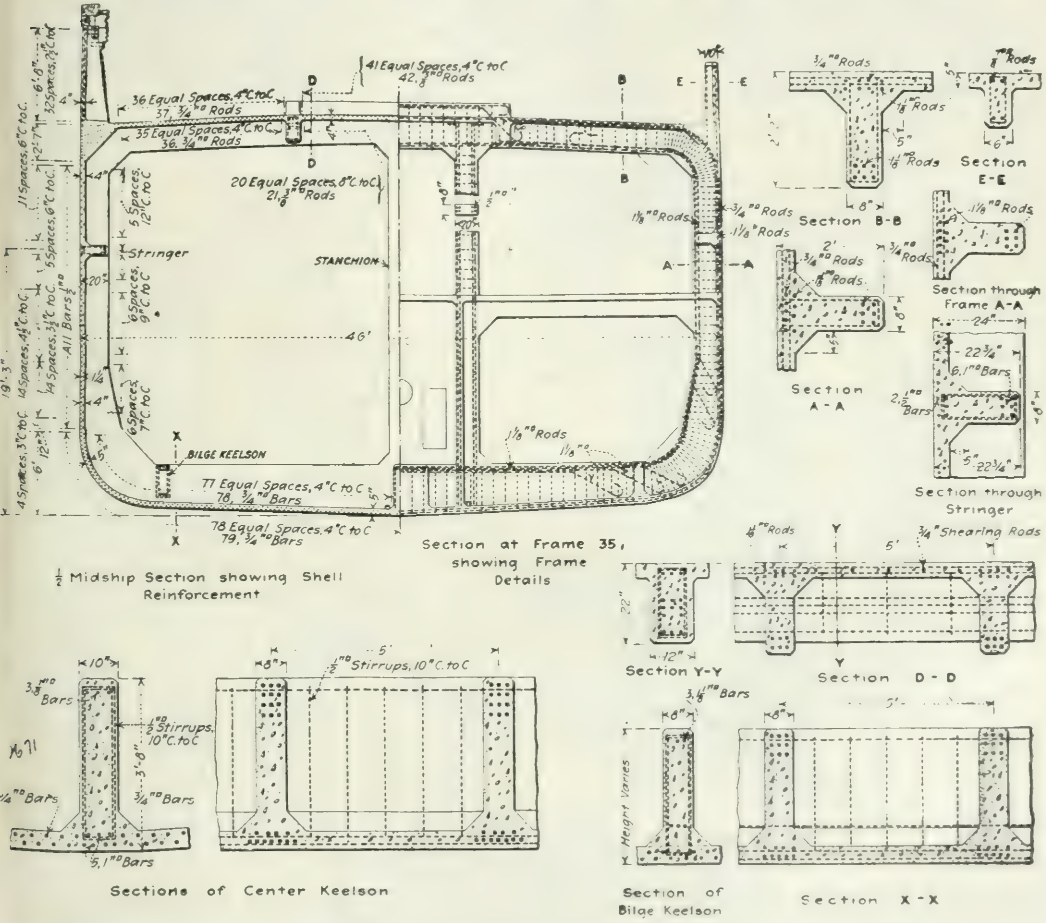
Two Cross Sections.

American Concrete Ship Design.

In the general shaping of the hull very little change from the standard wood ship has been made as a concession to the use of concrete. The midship section, which continues for about 35 per cent. of the length, is practically square. There is a slight batter in the bridge deck bulwark, and a rise of 9 in. in the bottom from the centre to the bilge keelsons.

Stiffness of the bottom is aided by one centre keelson and two bilge keelsons, the former turning to make stern and stem posts, and the latter following the curve of the hull and ending at the collision bulkheads. These keelsons are concrete girders reinforced with rods in their upper and lower sections and tied together with frequently spaced stirrups. They frame into the transverse frames of the vessel, which are spaced 5 ft. apart on centres. These frames are reinforced-concrete girders turned at the corners to meet the curve of the hull and re-entering at the main deck to form the transverse deck girders which carry the deck and serve as cross-braces for the side members of the frames. The bridge deck bulwark is in effect a continuation upward of the shell of the ship, being formed of girder frames and an outer shell. It is provided with an expansion joint about amidships. The main frames are additionally stiffened by longitudinal, horizontally-placed stringers about three-quarters of the way up the frame.

Integral with the main frames is the shell, a continuous, reinforced-concrete plating 5 in. thick on the bottom and up to a point 6 ft. above the base line, and 4 in. thick through the remainder of the hull to the deck line. The main deck is also a 4-in. reinforced-concrete slab continuous except for the hatch openings, which are stiffened by the usual combings.



½ Midship Section showing Shell Reinforcement

Section at Frame 35, showing Frame Details

Sections of Center Keelson

Section of Bilge Keelson

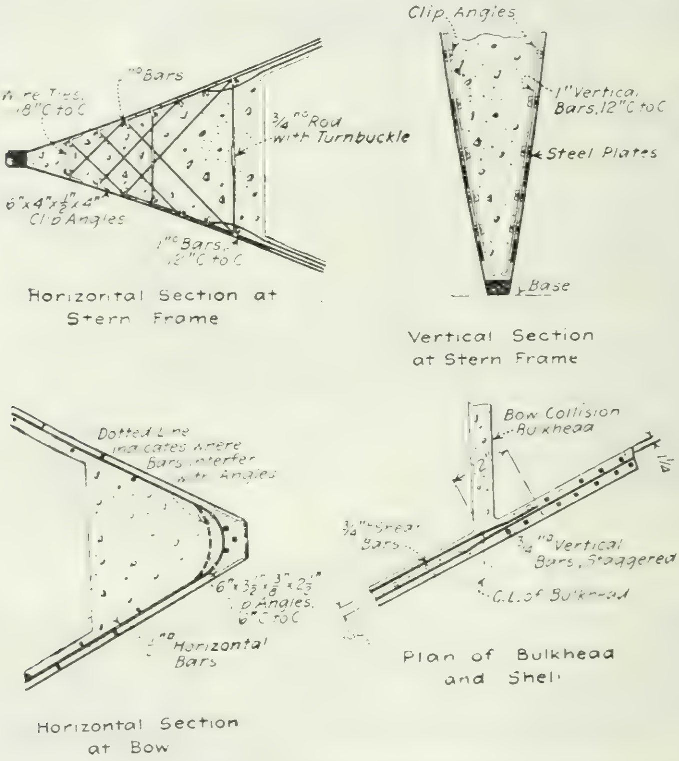
Cross-Frames and Shell in one of the Midship Sections

American Concrete Ship Design.

The shell is reinforced at its outer and inner faces with ½-in to ¾-in. square bars running around the shell parallel to the water line, and spaced at distances varying from 4 in. to 12 in. c. to c., as shown on the cross-section drawing. These rods are designed to be placed 1¼ in. from the face of the concrete on both outer and inner faces.

In addition, there are vertical $\frac{3}{4}$-in. shear bars between the horizontal rods spaced on varying centres. They extend around the entire shell and deck. The detail, a heavy connection forming in effect a longitudinal girder between the shell and the deck is shown in one of the drawings.

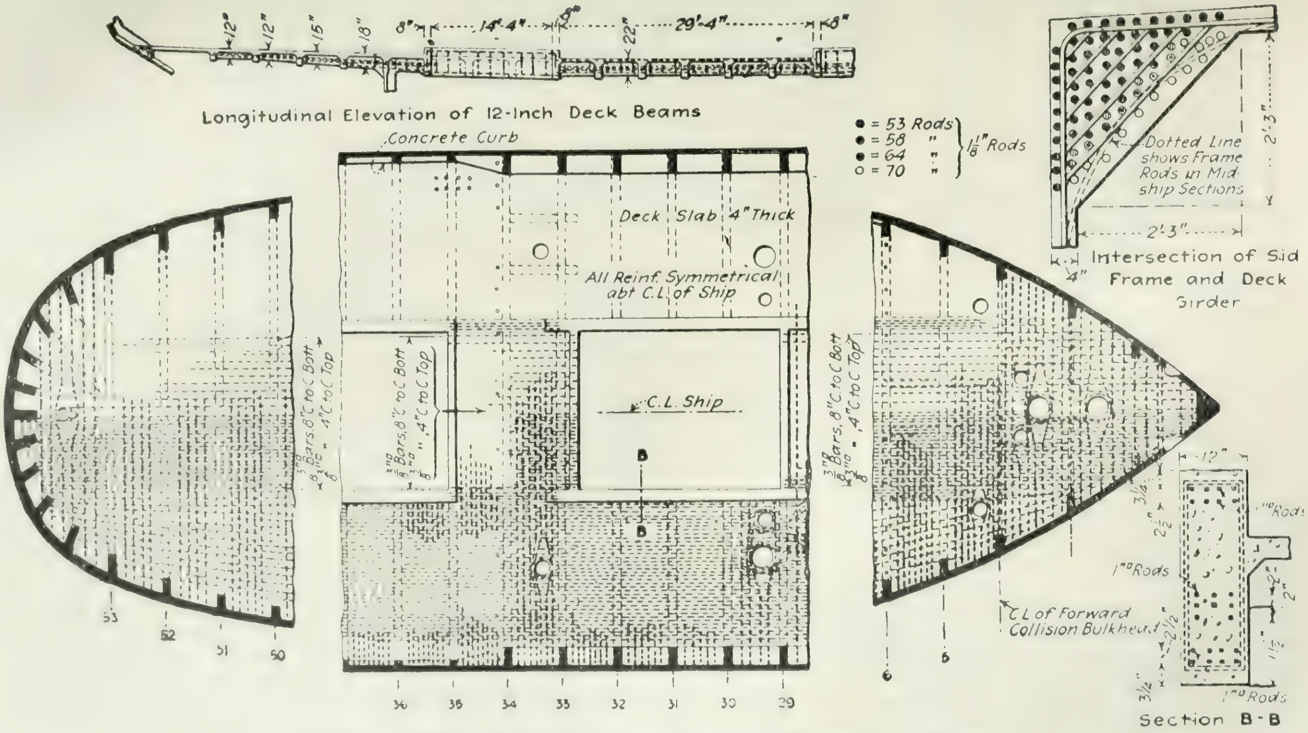
Between hatches in the cargo holds the deck beams have intermediate supports in the way of reinforced-concrete stanchions designed as columns, these stanchions being braced longitudinally at about half their height with reinforced-concrete struts. In the stern half of the boat the shaft tunnel is of reinforced-concrete framing, and the stanchions are supported on the cross-beams in the shaft-tunnel roof, which in turn span between short posts on either side of the tunnel.


Wire Ties, 18" C to C
"○ Bars
¾"○ Rod with Turnbuckle
6"x4"x½"x4" Clip Angles
1"○ Bars, 12" C to C
Horizontal Section at Stern Frame
Clip Angles
1" Vertical Bars, 12" C to C
Steel Plates
Base
Vertical Section at Stern Frame
Dotted Line indicates where Bars interfere with Angles
6"x3½"x⅜"x2½" Clip Angles, 6" C to C
½"○ Horizontal Bars
Horizontal Section at Bow
Bow Collision Bulkhead
2"
¾"○ Shear Bars
¾"○ Vertical Bars, Staggered
C.L. of Bulkhead
Plan of Bulkhead and Shell

American Concrete Ship Design.

Foundations for the engines and the boilers are on steel-plate girders footing on an extra framing of longitudinal reinforced-concrete girders running parallel to the keelsons.

Four transverse watertight bulkheads are provided. Two are collision bulkheads near the bow and the stern, and two enclose the engine-room space. Details of these bulkheads are given in one of the drawings. They consist of concrete slabs reinforced with transverse and longitudinal steel, and backing against vertical stringers and beams which frame into the main frames and deck girders. The engine-room bulkheads are slabs stiffened by vertical beams



Main Deck Reinforcement and Details similar to ordinary Reinforced Concrete Floor.
AMERICAN CONCRETE SHIP DESIGN

extending from short stringers in the bottom between two frames to similar stringers framing into the deck beams.

A special effort has been made to avoid sharp turns in the steel reinforcement, particularly in the main frames which are turned on long radius curves. Steel reinforcement in the hull will be $\frac{1}{2}$ in. and $\frac{3}{4}$ in. in diameter. Larger rods, as shown in the illustration, are in the interior framing. All reinforcement will be continuous, though the exact method of insuring this continuity has not yet been decided. Neither has the exact nature of the aggregate been settled, although experiments have been made with various light-weight aggregates which seem to promise a possibility of a concrete weighing less than 110 lb. per cu. ft., with a strength of 4,000 lb. per sq. in. at 28 days.

An analysis of the ship to determine its stability shows that the metacentric heights in the light and full-load conditions are respectively 2·15 ft. and 2·2 ft. This is well within the limits of present practice for vessels of this type and size. The freeboard amidships at the side is 4 ft. 9 in.

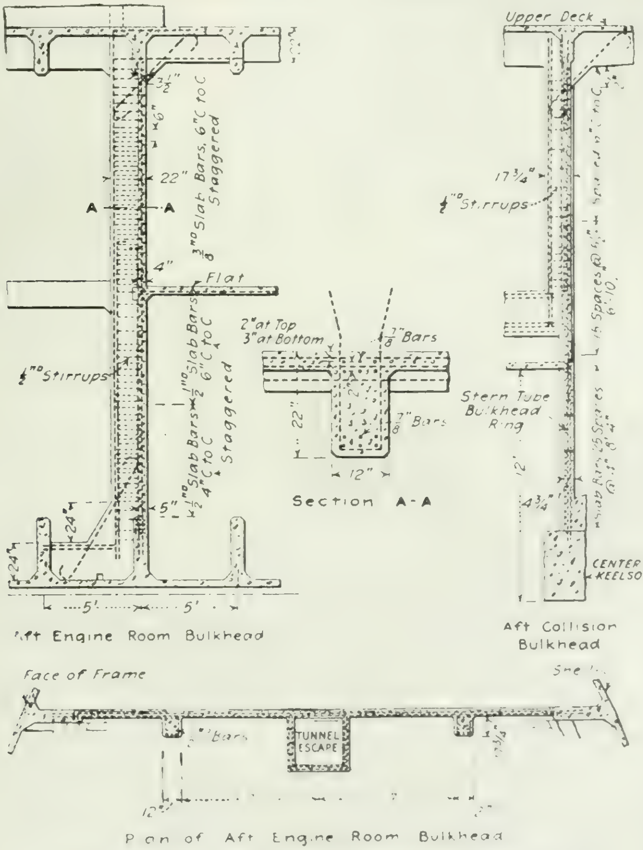
As this is a seagoing vessel, it has to be analysed to take care of the extreme condition of a ship in open ocean. Standard practice for the longitudinal analysis has been followed—that is, the same basic assumptions as to length, depth and form of wave and the same method of procedure as is standard in analysing steel ships was followed throughout. Hogging and sagging analyses were made for five conditions of load and sea. The strength of the ship's shell was determined, analysing the ship as a hollow beam with tension and compression going to the bottom and deck. The results of the analyses are shown in Table II. The strength of the shell plating as a slab spanning the frames was considered in combination with longitudinal flexural stresses. The Concrete Ship Department made analyses of the frames for conditions due to different loadings of the hull and to transverse rolling. This transverse section was designed to stand outside water pressure with water to the gunwales and with minimum cargo load, with maximum cargo load and a sagging draft of 15½ ft., and in listed positions with loading both light and heavy.

For all these conditions of loading the frames were designed to have stresses not to exceed 16,000 lb. per sq. in. in the steel and 1,500 lb. per sq. in. compression in the concrete. Bulkheads were designed to carry a head of water on either side up to deck. The collision bulkheads fore and aft were designed for 1,500 lb. per sq. in. in the concrete and 16,000 lb. per sq. in. in the steel. Steel stress in the engine-room bulkheads was advanced to 20,000 lb. per sq. in. The deck was designed to carry 5 ft. of water or its equivalent, which is somewhat in excess of the loading on the decks of standard steel ships being built by the Emergency Fleet Corporation.

Extra strong and a more plastic concrete is expected to be achieved by the use of a specially fine cement. Any standard Portland cement which will meet the Government specifications may be used, provided the fineness is increased so that at least 90 per cent. will pass a No. 200 sieve. This is hoped to give a concrete of 4,000 lb. per sq. in. compressive strength at the end of 28 days.

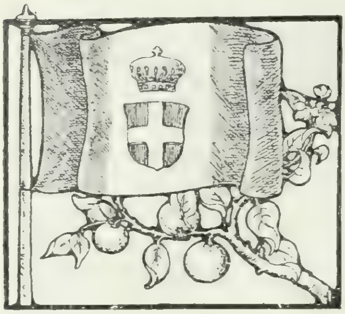
TABLE II.
STRESSES IN GOVERNMENT 3,500-TON CONCRETE SHIP.

Condition.	Maximum Bending Moment Foot-Tons.	Maximum Tons per sq. in. Fibre Stress in—		Lb. per sq. in. Fibre Stress in Concrete.
		Deck Reinforcement.	Keel Reinforcement.	
Ship without cargo, hogging	25,175	5·53	2·80	728
Ship fully loaded, hogging	37,000	5·63	2·95	766
Ship without cargo, sagging	14,400	1·28	2·63	270
Ship light with enough cargo in forward hole to trim sagging	11,960	1·07	2·19	210
Ship fully loaded, sagging	9,400	0·84	1·72	70



Bulkhead designed to take full head of water inside hold of vessel.
AMERICAN CONCRETE SHIP DESIGN.

With a standard 150-lb. concrete it is estimated that the ship will contain 1,761 tons of concrete, 400 tons of reinforcement steel, and 811 tons of wood, fittings, machinery and equipment, making a total of 2,970 tons, as shown in Table I. That is, the steel in the reinforced-concrete ship will be about one-third of the amount of steel in the steel ship of equal capacity.



CONCRETE BRIDGE IN ITALY ON THE RIVER ADDA, AT BRIVIO.

(Translated by DR. A. B. SEARLE.)

An important and interesting bridge, carried out entirely in concrete, has recently been completed in Italy, and we present herewith a few particulars and illustrations of same.—ED.

THIS bridge, giving access to the railway station of Cisano Bergamasco, is entirely constructed of concrete, and is 444 ft. in length and 30 ft. in width, with a 24-ft. roadway, flanked by two raised footpaths, each 2 ft. 7 in. wide. The roadway is about 26 ft. above the average level of the river. The span of the centre arch is 177 ft., and that of each side arch is 144 ft. The arches are each supported on two massive pillars and shoulders, built of concrete on a group of concrete piles made on the " Considère " system, driven for a length of 43 to 53 ft. through the muddy bottom of the river to the solid ground beneath by means of a steam hammer weighing 4 tons. Some of these piles were driven at an inclination of 1 : 13.

The factor of safety of the piles is about 10 ; the normal load of each pile averages 35 tons. The weight is distributed uniformly on the piles by means of a superposed concrete slab about 3 ft. thick.

The foundations of the structure are protected by a pitch pine shuttering 5 in. thick.

Each pillar measures 43 ft. by 13 ft., and rests on 48 steel-shod piles of square section and 14 in. side. The sole of the roadway is 5 in. thick ; beams 12 in. by 30 in. are placed transversely to vertical bars 11 in. by 24 in., and to longitudinal external beams 18 in. by 40 in. Each of these beams is provided with a support of round iron rods of about 64 sq. in. cross-section, fitted with collars and coupling irons.

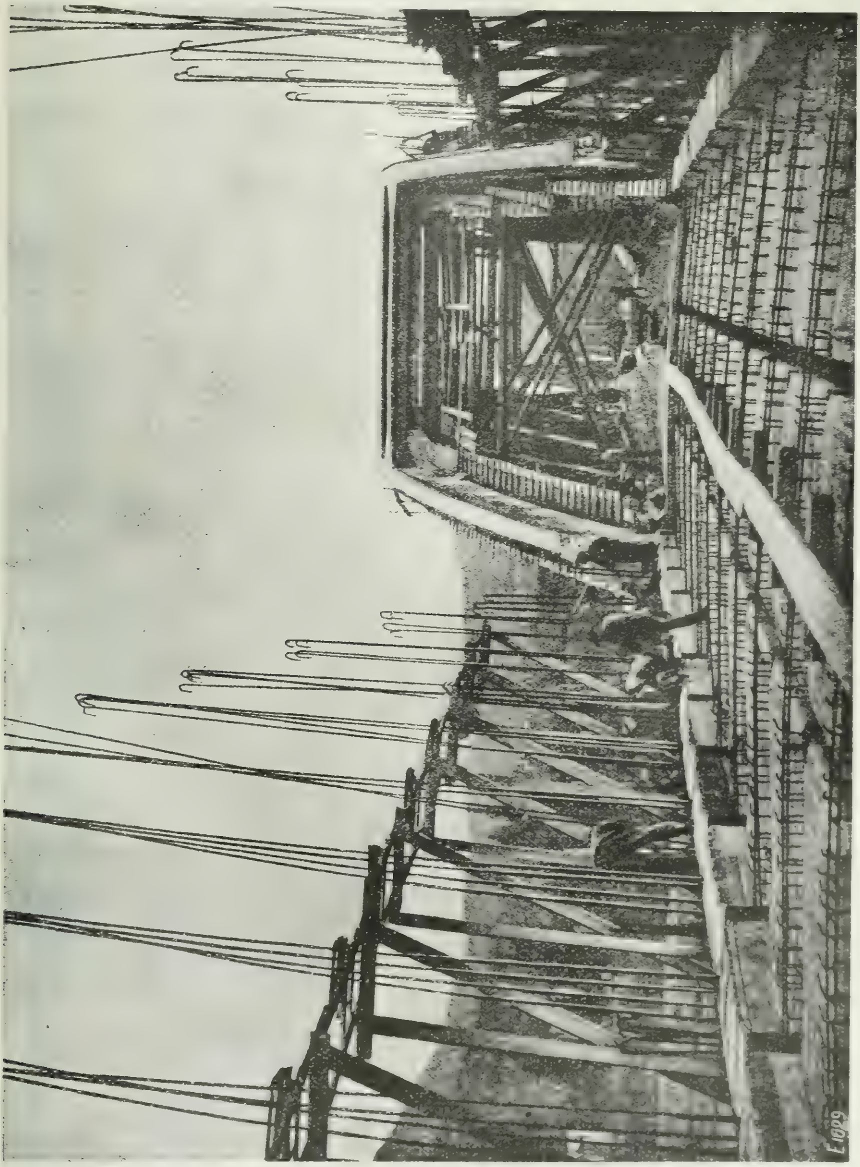
Each beam makes contact with pillars and shoulders by means of cast steel rollers, which allow the free expansion of the upper platform with variations in temperature.

The concrete roadway is protected by a layer of waterproof asphalt with a layer of concrete and gravel on it.

The edges of the two footpaths are provided with L irons ; the paths are paved with small pressed concrete tiles. The parapet wall of the bridge is of cast ironwork.

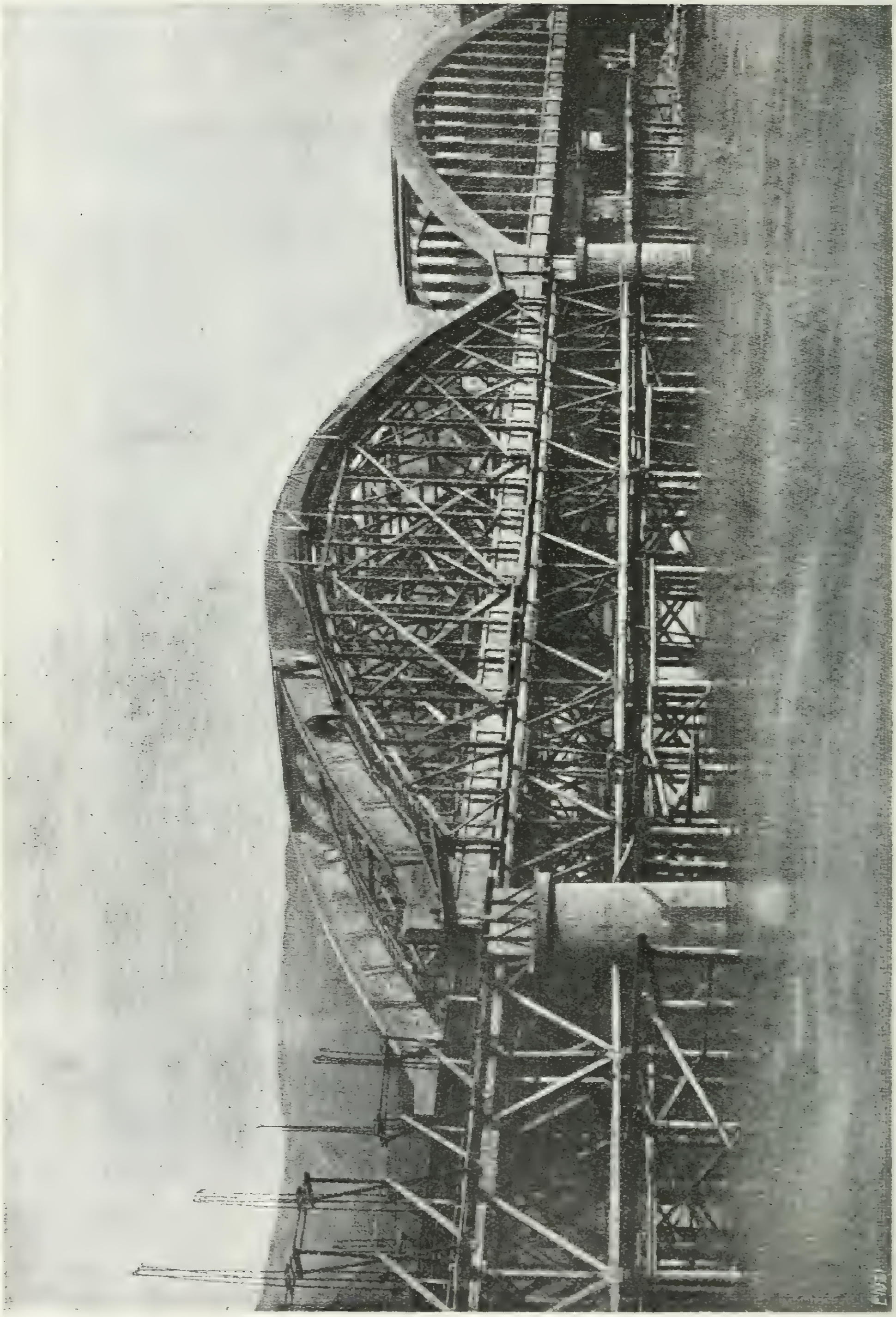
The pillars are chiselled, and all the exposed parts of the concrete have been carefully plastered with cement mortar.

The bridge was designed to carry a double-track electric tramway, a steam roller of 22 tons, and for a dense crowd of people calculated at 10 cwt. per square yard.



The Framework of the Road Platform and Vertical Rods.
A Concrete Bridge on the Adda, Italy.

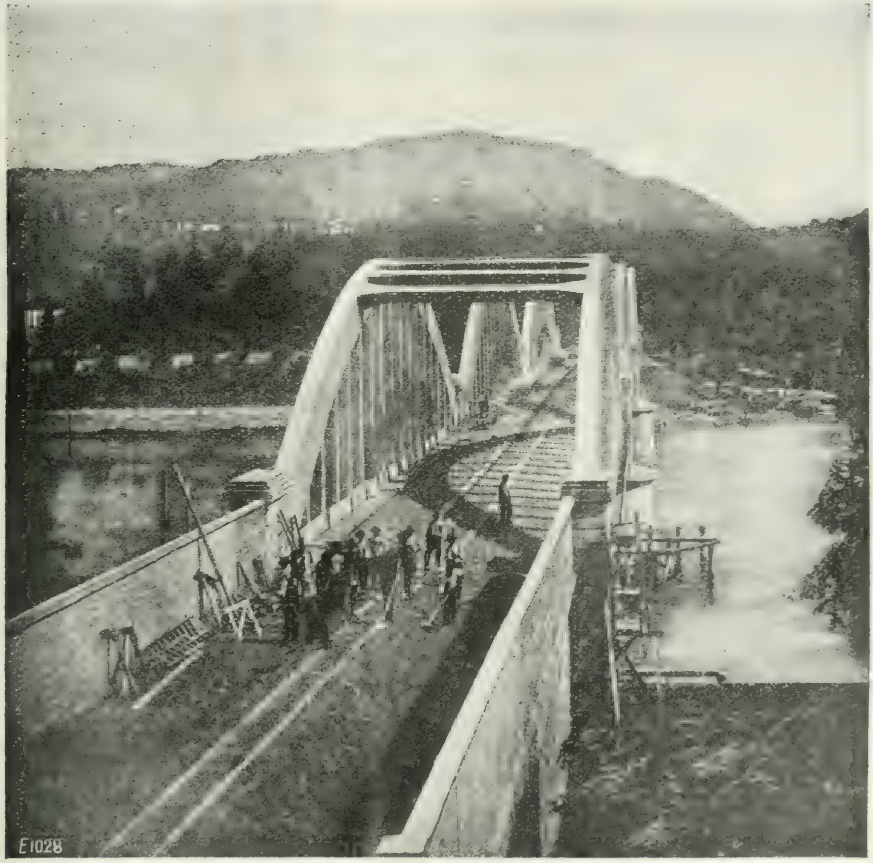
The equilibrium was calculated on the theory of an elastic arch with rigid cross-bar; the axis of the arch was made to coincide with the curve of the pressures under the action of the permanent load.



View showing progress of the work in three parts.
A Concrete Bridge on the Adda Italy.

In order to take into account the most favourable positions of the moving weights, the lines of influence of the bending movements were traced separately for each section of the archway.

Such dimensions and supports were given to the concrete structure that the specific pressures of the materials were in conformity with the regulations of the Italian Government, which specifies a tensile strength of 14,000 lb. per sq. in. for the reinforcement and a compressive strength of 560 lb. per sq. in. for the concrete, with the exception of the compressed parts of the crowned arches and of the supports, where the specific pressure reached 980 lb. per sq. in. This portion of the structure was fitted with a special iron framework.



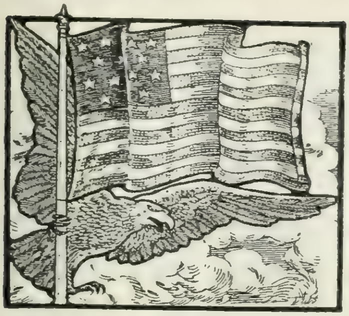
View towards Asano along the Roadway.
Concrete Bridge on the Adda, Italy.

The work was commenced at the end of 1913, and notwithstanding so much of it being carried on during the war, which made supplies and labour very difficult, the bridge has been open to the public since May 1st, 1917.

At the static test, which took place about the middle of 1916 in the presence of competent authorities, each of the three parts of the bridge was loaded with a layer of gravel 21 in. thick to correspond to an accidental overload of 200 lb. per sq. ft. Under this burden the maximum elasticity registered by the " Fleximeter " was 1/5th in., or about 1/8,000th of the net curve of the arch, an elasticity of 1/12,000 being allowed in the contract.

Altogether 3,500 cu. yds. of sand and small gravel, about 700 tons of second quality Portland cement, and about 300 tons of round iron were used. The cost of the work (not including the expropriations) was £20,000, as estimated.

The work was carried out by the Societa Anonima Italiana Ferrobeton of Rome, to whom we are indebted for our illustrations and particulars.



CONCRETE IN SEA WATER.

By R. J. WIG and L. R. FERGUSON.

IV.

Continued from August issue. In the present articles the authors show that all well-made Portland cements may be considered safe, as may also sea-water guaging, but great care should be exercised in choosing the aggregate.—ED.

In the previous articles the authors have shown that unless protected against abrasion plain concrete is apt to disintegrate following the chemical attack of sea water on the softened interior, and that reinforced concrete is subject to percolation which permits the rusting of the reinforcing steel and subsequent failure of the concrete. It is therefore necessary, in order to resist this action, to have as good, dense concrete as possible and to reject any material, be it cement, aggregate or water, which may tend to accelerate the sea-water disintegration. In this article will be taken up the selection of the various materials.

All well-made Portland cements will resist disintegration in sea water *if properly used*. This statement must be defended, as many engineers are of the opinion that no cements are durable in sea water, or at best only such cements as have some peculiar composition. This belief is founded largely upon laboratory tests or investigations made under abnormal conditions of test, or a misinterpretation of data obtained from the chemical analysis of concrete which has disintegrated in sea water. No more conclusive evidence is required by the engineer to support the statement that all well-made Portland cements will resist disintegration in sea water if properly used than the fact that concrete structures have been standing in sea water for the past 30 years and more without showing any deterioration. Let us see what the experience has been with Portland cements of widely different composition.

During the period from 1888 to 1890 many concrete bridge piers were built along the Bay of Fundy in Nova Scotia by the Dominion Atlantic Railway and the Provincial Government. J. B. White & Brothers' English Portland cement was used, and these piers, where protected from abrasion or not exposed to severe erosion, are in excellent condition, as shown in *Fig.* 18.

In New York harbour are several miles of bulkhead walls of which the substructure is made of precast concrete blocks weighing from 40 to 80 tons. These walls were built at various periods dating from 1877 to the present, and various brands of Portland cements were used. Two of these blocks were raised after immersion for 10 years, and their perfect preservation can be seen from the view shown in *Fig.* 19.

At different times from 1892 to 1900 cement-mortar jackets were placed around the wood piles of the Spreckels wharf at San Diego, California. *Fig.* 20 shows, in excellent condition still, the top of one of these jackets, placed in 1892.

There are a great number of structures built since 1900 which show this same excellent preservation in sea water; in fact there are no authentic cases of disintegration of concrete which is at all times wholly immersed that are not accounted for by the use of poor materials or workmanship. Among the cements used in the concretes which have shown practically no deterioration after a long period of exposure are those given in the accompanying table. An examination of this table shows that the composition varies between relatively wide limits—particularly the alumina, magnesia and sulphur trioxide, which are the three elements which are generally considered very deleterious by many engineers.

CHEMICAL COMPOSITION OF CEMENTS USED IN CONCRETE WHICH HAS RESISTED SEA-WATER ACTION

	Percentage of Various Constituents							
Brand	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Loss	In. Res.
Alpha	20·88	2·65	7·89	62·54	2·62	1·23	1·06	0·27
Atlas	21·30	2·55	7·35	61·48	3·21	1·53	1·77	0·22
Dykerhoff (German)	21·52	2·90	6·54	62·96	2·41	1·40	1·76	0·27
K. B. & S. (English)	19·75	5·01	7·48	61·39	1·28	0·96	—	—
Lehigh	22·70	2·30	5·72	63·04	3·19	1·59	0·93	0·19
Old Dominion	20·82	2·65	6·95	62·66	2·68	1·62	2·20	0·40
Phœnix	21·82	2·20	6·44	62·76	3·33	1·58	1·55	0·30
Pennsylvania	21·84	2·30	6·14	62·38	3·91	1·61	1·29	0·45
Rosendale (Natural)	25·80	4·60	11·44	33·51	16·38	1·10	7·41	--
Santa Cruze	22·26	1·85	8·23	63·48	1·64	1·72	1·23	0·41
Vulcanite	22·76	2·18	7·58	62·98	2·09	1·30	0·98	0·15
Washington	22·96	1·90	4·64	64·38	1·84	1·38	2·71	0·28
White Bros. (English)	21·17	4·14	7·35	61·94	0·91	1·38	1·65	0·87

Providing the cement is properly manufactured, one containing 8 per cent. of alumina will resist sea-water action just as well as one containing only 4 per cent. The solubility experiments made by P. H. Bates, as noted in Technologic Paper No. 12 of the Bureau of Standards, show that a cement containing only 3 per cent. of alumina and 7·5 per cent. of iron oxide may be even more soluble in sea water than one containing 8·5 per cent. of alumina and less than 1 per cent. of iron oxide. The most convincing proofs to the engineer, however, are the many structures which have been made of cements containing more than 7 per cent. of alumina and have withstood sea-water action for a period of years without disintegration or deterioration.

Many engineers have an idea that magnesia is deleterious in cement because when a sample of concrete which has disintegrated in sea water is chemically analysed it is found to contain a relatively high amount of this material. If a comparison has been made of the amount of magnesia in the cement used with the amount found in the concrete after disintegration had occurred it would have been found that the magnesia content had materially increased.

The increased magnesia found in the disintegrated concrete is precipitated from the sea water as a magnesium hydroxide. The magnesia in the cement originally is wholly inert to the sea water and in fact may be considered one of the most stable elements of the cement. For use in sea water it is really preferable to have the magnesia run as high as permissible without causing unsoundness—that is, about 8 per cent.

So many structures have been built in sea water of cements containing from 3 to 4 per cent. (the maximum permitted by American specifications until 1917) of magnesia that are now wholly sound where not exposed to abrasion that the evidence is conclusive from the practical as well as the theoretical and laboratory source. Magnesia within limits is not a deleterious element in the cement.

Until 1917 the American specifications limited the sulphuric trioxide content of cement to 1·75 per cent. Therefore practically no cements have been used in sea water in this country which contained more than this quantity, and the majority of American cements range between 1·30 and 1·60 per cent. Most of the sound structures on the North American coasts are made of such cements, which is evidence that up to this limit, at least, the sulphuric trioxide is not detrimental.

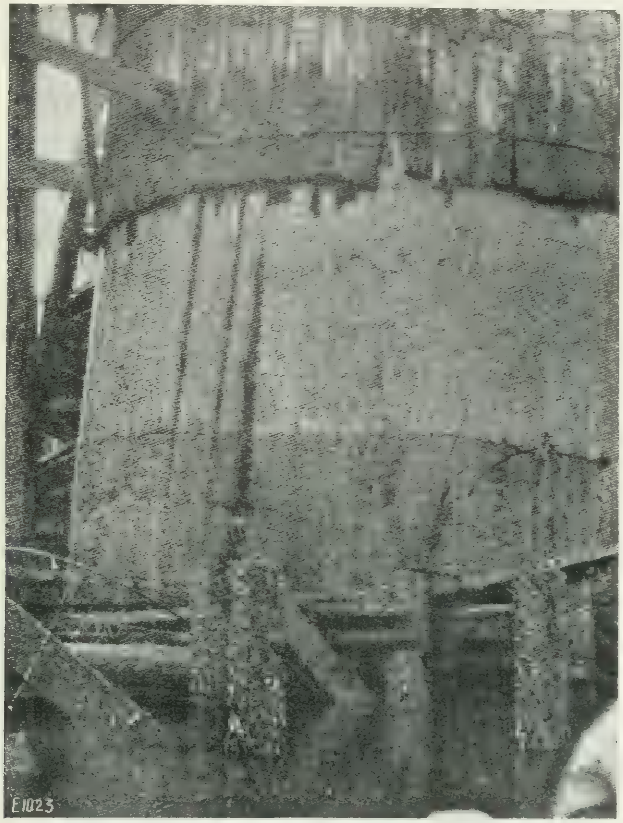


FIG. 18. PIER BUILT OF ENGLISH CEMENT 25 YEARS AGO.
Concrete was protected and is still in good condition.

There are concretes that have been standing in European waters for 10 or 15 years which are made of cements containing from 2 to 2·5 per cent. of sulphuric trioxide without showing any evidences of disintegration below the water line.

Solubility tests made by P. H. Bates show that there is no difference in the solubility in sea water of cements containing varying amounts of sulphuric trioxide up to 1·75 per cent., this being the maximum amount in the cements he investigated. Thus all available data on this subject concord and show that there is no advantage in limiting the content of sulphuric trioxide below 2 per cent., which is now allowed by American specifications.

The most vulnerable and chemically active material in a cement when exposed to sea water is the lime, which comprises 60 per cent. or more of the composition. It is not possible to decrease the quantity of lime in the cement appreciably without destroying its cementing and hydraulic properties.

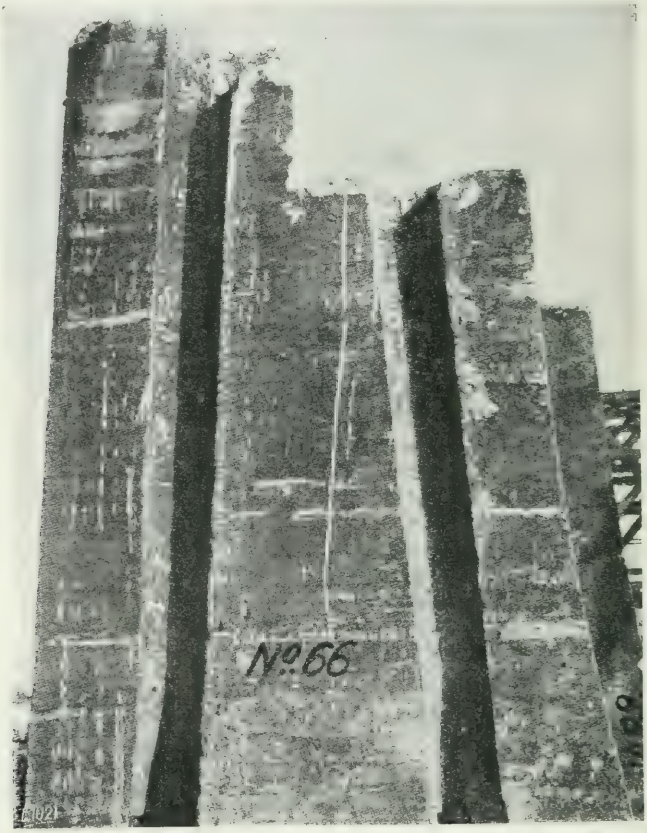


FIG. 19. CONCRETE BLOCKS SUBMERGED IN NEW YORK HARBOUR 10 YEARS. No disintegration visible after removal to air.

To summarise, it may be stated that, contrary to the opinion of many, there is no definite relation between the chemical composition of properly manufactured Portland cements and the ability of concretes made from them to resist disintegration in sea water. If properly manufactured and properly used, all normal Portland cements are durable in sea water. The constituents of such cements generally range between the following limits: Silica, 19-25; alumina, 4-9; iron oxide, 2-6; lime, 60-65; magnesia, 1-5; sulphuric trioxide, 1-2.

SEA WATER CAN BE USED IN MIXING.

Sea water or brackish water can be used for mixing unreinforced concrete without deleterious effect. Nothing but fresh water, however, should be used in mixing concrete above water which is to be reinforced. The salts contained in sea water have no appreciably deleterious effect upon the chemical action which takes place when cement sets. In reinforced work, however, the presence of the salts may have an injurious effect upon the embedded metal in accelerating corrosion above the water line.

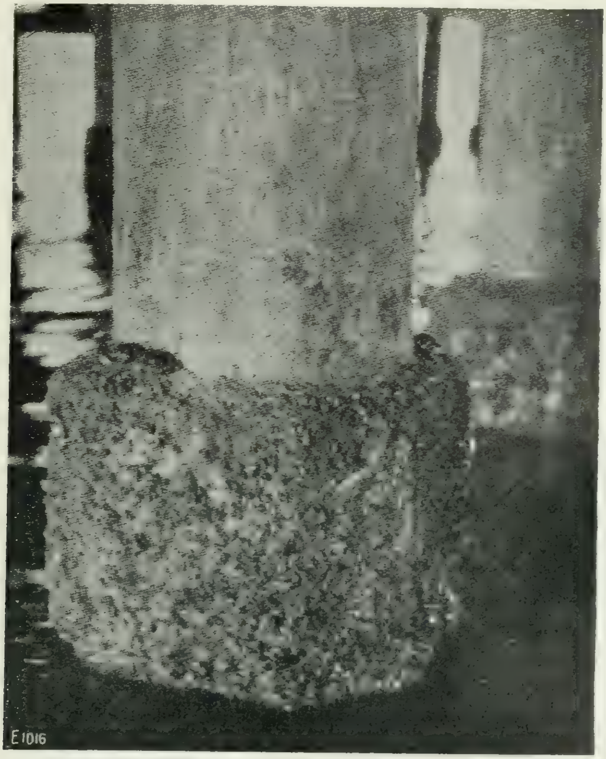


FIG. 20. MORTAR JACKET EXPOSED TO SEA WATER 22 YEARS. NO DETERIORATION.

A study of what has been done and the results obtained will throw much light on this phase of the subject. Practically all of the concrete structures built along the Bay of Fundy in Nova Scotia were made of concrete guaged with sea water. In *Fig.* 18 is shown a bridge pier on the Bay of Fundy. These structures have been personally examined by the writers and are in excellent condition except where abraded. The concrete is of excellent quality and shows no peculiar characteristics which would indicate that sea water instead of fresh water had been used in mixing.

The one extensive American operation upon which sea water was used in mixing the concrete is that of the Florida East Coast Railway for the work between Homestead and Key West, Fla. (See *Fig.* 21.) Several hundred pier structures have been built since 1909, involving several hundred thousand yards of concrete, practically all of which has been guaged with sea water. These structures, while not very old, show no deleterious effect whatever from the use of sea water.

A. B. Fletcher, state highway engineer of California, has used sea water in mixing concrete used in road construction without any effect on the quality of the concrete.

There have been a number of small marine structures built in this country n which the concrete was guaged with brackish or undiluted sea water, but no other extensive works. American specifications have quite generally required the concrete to be mixed with fresh water, and so we shall have to turn to foreign structures subject to sea-water action to see what the effect has been of mixing sea water with the concrete.

Sea water was used in mixing concrete for the construction of the marine railway piers in Algoa Bay by the Government at Port Elizabeth, South Africa, in 1902. This pier was in excellent condition in 1914 and showed no defects which would indicate that the sea water was detrimental. There are numerous other extensive marine structures in good condition in this same district which were built at different periods since 1878, and it has generally been the custom for the Government to use sea water for mixing concrete for this class of work.

A half-and-half mixture of sea water and fresh water was used in mixing the concrete for the quay walls and breakwaters at Salonika, Greece, constructed prior to 1906 by a French syndicate. These works were all reported to be in excellent condition in 1914 where not abraded.

The Government of Tasmania used sea water in mixing the concrete for the construction of the Huon lighthouse in 1906. This was reported to be in good condition in 1915 and showed no deleterious effect from the use of sea water.

British specifications have generally, for many years, permitted the use of sea water for mixing unreinforced concrete. Among specific cases may be cited the sea wall built in 1909 at Methil, on the Firth of Forth, about 18 miles north-east of Edinburgh. This was reported in 1915 to be in good condition. The specifications of 1913 for the new works of Aden Port Trust, Aden, Arabia, state that "the water for mixing concrete may be sea water"; also those for the extensive sea wall and dock works at Rosyth naval base on the north shore of the Firth of Forth, about five miles south of Dunfermline, Scotland, and for the dock at Newport, Monmouthshire, England, which was built in 1905, sea water being used in mixing the concrete.

Where sea water is used less than 0·1 lb. of cement is required to react with the salts in each gallon of water. If large masses are being poured and the concrete is mixed very wet a larger quantity of laitance will accumulate on the surface of the concrete than if fresh water were used. This added laitance consists mainly of magnesium hydroxide precipitated from the sea water.

If proper construction methods are followed there will be no difference in the appearance, workability, or resulting quality of unreinforced concrete, whether guaged with fresh or sea water.

It is well known that under conditions where oxidation of the steel can occur the presence of sea water has a most marked effect in hastening corrosion. That the corrosion of the steel is occurring in the exposed section of many reinforced concrete structures in sea water has been fully set forth in an earlier article, and therefore if sea water is used in mixing the concrete it will accelerate the oxidation. If the structure is exposed to stray electric currents the deleterious effect of the presence of the sea salts will be still more strongly emphasised, and disintegration from electrolysis may be rapid.

The same rules that apply to selecting fine aggregate for land structures also apply to concrete structures exposed to sea water, except that in Northern latitudes the sand should be selected so that it will produce a concrete of minimum porosity which will offer the greatest resistance to frost action. This practically eliminates natural sands and stone screenings containing large quantities of fine particles or dust, and also soft or porous aggregate.

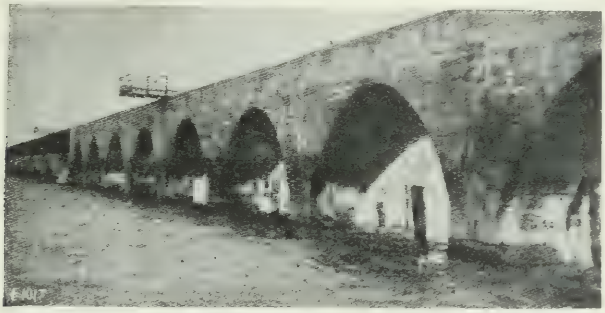


FIG. 21. FLORIDA EAST COAST PIERS.
Canal Sand and Rock were used in these piers, the guaging was done with sea water, but concrete is in good condition.

In the South where there is no frost, uniform, fine sea sand and relatively soft limestones, coral rocks and shell sand are successfully used. The relatively soft, so-called coral sand found off the Florida Keys has been and is now being successfully used by the Florida East Coast Railway in its very extensive marine structures, and by the United States Navy at Key West. *Fig.* 21 shows some of the concrete piers of the Florida East Coast Railway in which coral sand and rock were used as aggregate.

Seashore sand was used in making the concrete jackets on the wood piles at San Diego previously referred to and illustrated in *Fig.* 20. It has been successfully used in a number of other marine structures in the South. Shell sand was used in the construction of sea walls at Port Royal, S.C., built in 1899 and 1900. These walls, though poorly constructed, are still in serviceable condition. Some seashore sand was used in the construction of the piles of Municipal Pier at Santa Monica, California. This sand contained a small quantity of shale. These small pieces of shale have swollen in the concrete, causing it to crack and spall even though embedded as much as an inch from the surface.

It is always safe to use well-graded, clean, hard sand, but under certain conditions successful and wholly satisfactory work can be done in Southern latitudes with sands which would generally be considered wholly unsatisfactory. Where extensive works are contemplated it will pay to make a careful study of the available fine aggregate.

The statements made relative to the hardness of fine aggregate also apply to coarse aggregate—that is, in Southern latitudes under certain exposure conditions softer aggregate may be used than would be permissible in the North where frost conditions exist. Shale or other material which will expand when exposed to water and air should, of course, never be used. The partial or complete failure of several concrete structures has been caused by the use of aggregate containing only a small quantity of shale.

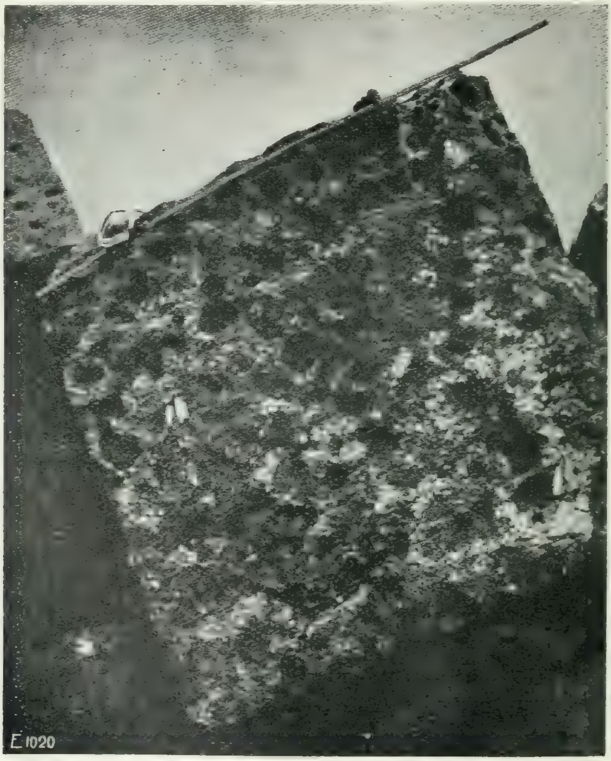


FIG. 22. CONCRETE BLOCKS AT PANAMA.
Show pitting where mechanical erosion takes place.

In 1886 the French made, at Panama, 580 concrete blocks of 1 : 2 : 3 mixture, using Portland cement, beach sand and conglomerate argillaceous sandstone. The blocks were used in shore protection at Cristobal. *Fig. 22* shows some of these blocks as they appeared in 1910. The holes seen here and there over the surfaces are caused by the disintegration of the embedded aggregate. The markings on the original surfaces are plainly visible on some of the blocks.

Some engineers will not use limestone as aggregate because they believe it disintegrates in sea water. But limestone, which is a calcium and magnesium carbonate, is stable and insoluble in sea water, and is therefore safe to use.

Gravels are preferable to crushed-stone aggregate, particularly for under-water work, because they mix and settle into place more easily. Either crushed stone or gravel may be used, however, if carefully handled. Bank-run gravel should never be used, as its quality is not uniform.

HOW ABOUT WATERPROOFING MATERIALS?

With the failure of concrete structures in sea water engineers have experimented with waterproofing compounds as a possible remedy. Structures were examined in which a number of these materials were used. In no case was there any difference in the appearance of the structure which would indicate that a waterproofing compound had been used, the same defects and deterioration being present in the treated structures as in those untreated.

In one case many concrete piles had to be discarded on account of the reduction in strength due to the use of a waterproofing compound. The piles were remade without the compound and were driven without breakage.

Complete failure of concrete containing compounds has also occurred in certain cases. Reinforced concrete containing waterproofing compounds has cracked and deteriorated in the same manner as the untreated reinforced concrete. It appears that at best waterproofing compounds are of doubtful value and their use is not recommended.

To sum up this matter of the effect of materials used in concrete subjected to sea-water action, it may be stated that :

1. All well-made Portland cements will resist disintegration if properly used.

2. The guaging of the plain concrete with sea water will not be deleterious if proper methods of construction are followed.

3. Aggregates should be carefully selected, particularly with the idea of securing density and toughness, although in localities where there is no frost action local materials, of what might be considered inferior quality may be successfully employed for unreinforced work. Where the conditions are severe, as along the north Atlantic coast, only the very best aggregate will produce concrete able to resist the action of the sea water.

4. Waterproofing compounds have no beneficial effect.

(*To be concluded.*)

A NEW CONCRETE COTTAGE CONSTRUCTION.

By ALBERT C. FREEMAN.
Author of "Small Estates Management," etc.

In the following article the author gives particulars and illustrations of a new concrete cottage construction for which he claims considerable saving in cost.—ED

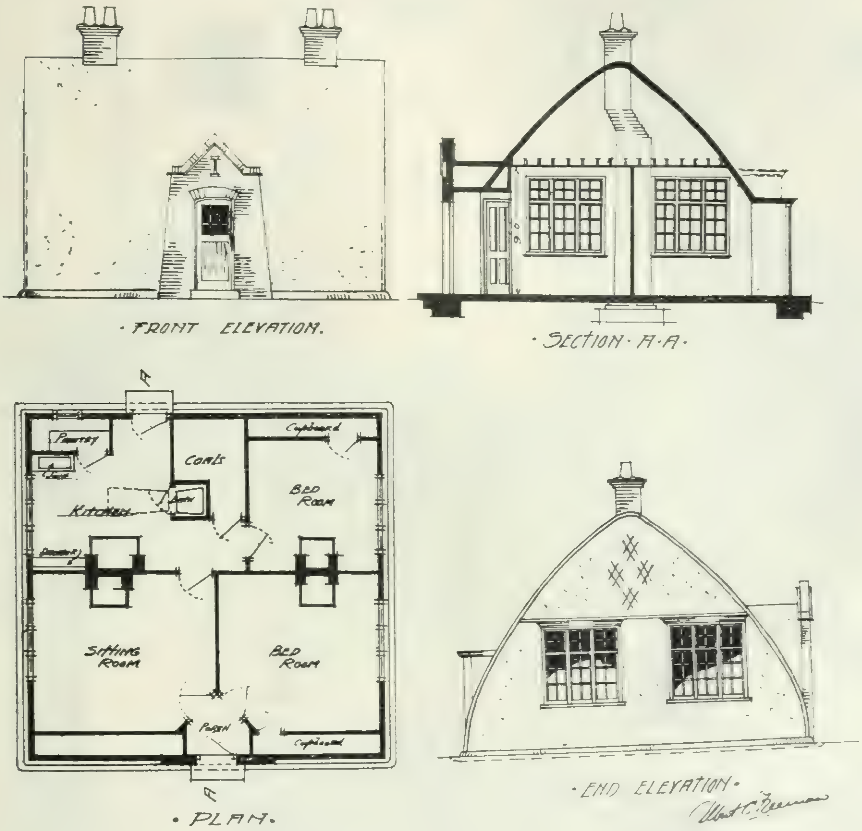
One of the many important questions to be considered by municipal authorities after the war is that of the housing of the working classes. The provision of new dwellings will be a most serious matter owing to the advance in the cost of all materials and the increased wages of the workmen. With a limited supply of raw materials, such as timber and cast-iron goods, and the inevitable shortage of bricks, tiles and slates, we shall be faced with the problem of a new form of construction—one that is cheap and easily carried out.

New ideas and new methods will have to be considered by those responsible for the carrying out of new building schemes. Concrete, which has now been so largely used in the construction of ships, will have to be more generally adopted for building construction in connection with small property. The raw materials are readily accessible in most localities, and it can be shaped with rapidity by the aid of a small amount of relatively unskilled labour. Many forms of concrete construction have been adopted, and during the war breeze blocks have been used to a large extent by H.M. Office of Works in the construction of temporary buildings. The question whether breeze blocks, as we at present know them, will be acceptable for permanent structures is open to question.

To meet the immediate after-the-war requirements I have designed a structure in an entirely new form, and have invented a simple form of reinforced concrete which will be quite as durable as that of brick and stone, while the cost of upkeep will be comparatively nil. The properties of reinforced concrete in building are so well known that there is no great difficulty in employing the material in any form, while for dwellings it is absolutely fire-resisting as it does not burn. A careful investigation has shown that no other material possesses the advantages of concrete, while the objections which have been urged against the use of concrete have been remarkably few and unimportant.

I have now invented a dwelling—for which a patent is being applied—which can be erected at a cost of at least 40 per cent. cheaper than any structure built of brick or stone with slates or tiles as a roof covering. The exact nature of the structure I am not at present in a position to state. I would point out that it will be of a reinforced character, and dispense with the use of timber in the roof, and, further, no rain-water pipes or gullies will be used for carrying off the water from the roofs. No slates or tiles are employed for covering the roofs, or lead dressings used. These items alone will entail a considerable saving in the cost of the structure.

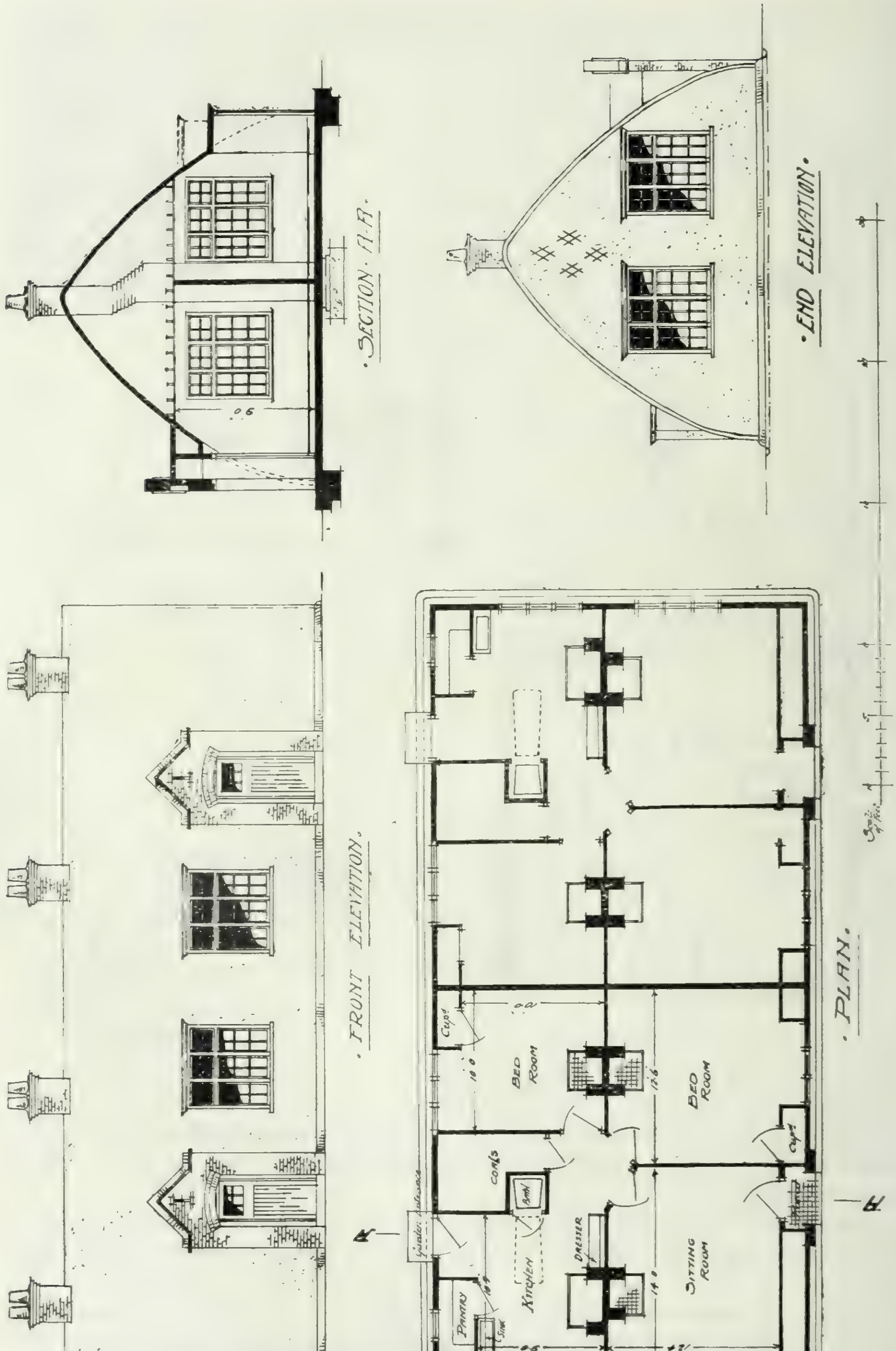
The whole of the exterior will be finished with rough cast cement plastering relieved with brickwork to the chimneys and the entrance porches, thus lending colour to the whole scheme, and giving a pleasing effect when surrounded with trees and foliage.



Proposed Concrete Cottages. Type "A."

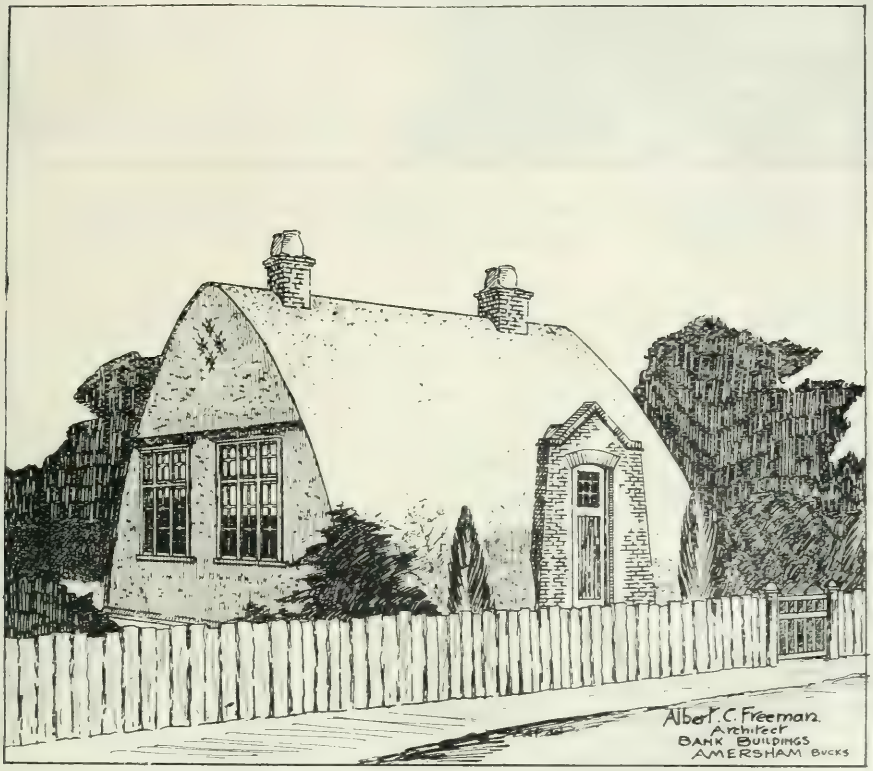
The interior walls and ceilings will be plastered, and the various apartments planned and fitted to meet the requirements of an up-to-date labour-saving dwelling.

The illustrations here produced show a pair of semi-detached cottages and a single cottage, each with a sitting room, kitchen, pantry, coal store, and two bedrooms. The question of the cost of these structures has been most carefully



Proposed Concrete Cottages. Type "B."

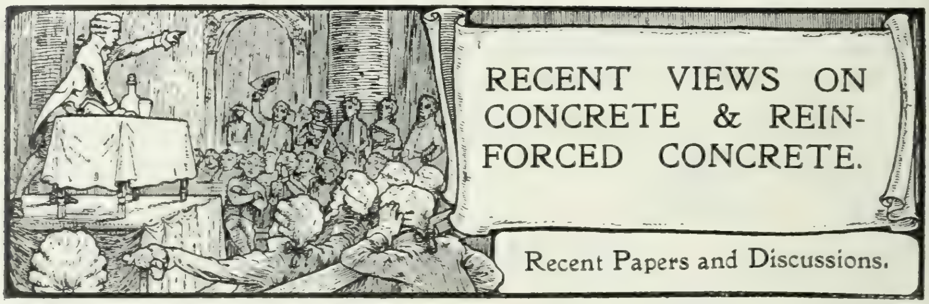
considered, and judging by estimates which have been received from builders of repute it is possible to erect these dwellings at a cost of least 40 per cent. less than the older form of construction.



General Elevation of Proposed Concrete Cottages, Type "A."

MEMORANDUM

Housing and Materials.—An interesting Paper on this question was read by Mr. W. E. H. Burton at the Bradford meeting of the Institution of Municipal and County Engineers. Among the many suggestions made were the following: Brick footways should be dispensed with and concrete substituted, while where subsidence is possible (as in colliery districts) disused wire rope makes an excellent reinforcement. Brick walls of 10-in. thickness, with a 1-in. cavity, are more effective in resisting driving rain than solid walls, unless the latter are more than 14 in. thick. Concrete lintels should be used in place of wood, doing away with the necessity for relieving arches, while they should be used also in fire openings with concrete hearths in place of trimmer arches. Joists and floors should be dispensed with at ground level, and concrete, cement, and "Pudlo" floors substituted. As regards upper floors, it might be feasible to adopt "a continuous mesh reinforcement to floor a complete block of dwellings in one operation at comparatively low cost." The use of local materials should be encouraged as far as possible, and while a certain amount of standardisation is advisable, this should never extend to window and door openings, as tending to restrict free treatment of elevations.



RECENT VIEWS ON CONCRETE & REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE AMERICAN CONCRETE INSTITUTE.

CONCRETE SHIPS.

By R. J. WIG and S. C. HOLLISTER.

At the recent annual meeting of the Concrete Institute considerable attention was devoted to questions relating to concrete shipbuilding. An interesting paper was that read by Messrs. Wig and Hollister, attached to the U.S. Government Shipbuilding Department. The following is an abstract of the paper dealing with construction problems The other part of the paper discussing design will appear in a subsequent issue.

CONCRETE MUST BE LIGHT AND STRONG.

THE first thought of most engineers with regard to materials for the concrete for a ship is to use such as will provide the densest mixture possible. Concrete of high density also has a high unit weight. Our problem is fourfold : The concrete must be durable and impermeable to water ; it must have a compressive strength of at least 4,000 lb. per sq. in. at twenty-eight days, and a minimum weight. To meet these conditions we have determined upon the use of a rich mortar mixture.

Any standard Portland cement which will meet the specifications of the United States Government may be used, provided the fineness is increased so that at least 90 per cent. will pass a No. 200 sieve. The greater fineness is required in order to obtain greater strength and a more plastic mixture. Such a cement is also more volume constant.

For the present the maximum-size aggregate is limited to ½ in. A sand and gravel or a volcanic ash or specially burned clay may be used. The commercial future of the concrete ships is in large measure dependent upon obtaining a light-weight concrete. Investigations made are quite promising. The strength and weight of one of these mixtures which meets our requirements is as follows : 1 part cement to 1 part special fused clay below ¼-in. size to 2 parts same aggregate between ¼-in. and ½-in. size, had a compressive strength of 3,380 lb. per sq. in. at seven days, and 4,350 lb. per sq. in. at twenty-eight days. It weighed 106 lb. per cu. ft. in a saturated condition.

With the use of this material the ratio of the dead weight to total displacement will be 62 per cent. for the 3,500-ton ship as compared with 65 per cent. to 68 per cent. for a steel ship and 53 per cent. for a wood ship.

No integral waterproofing compounds of any kind will be used in the mixtures.

FORMS MUST BE ACCURATE.

The form problem is a most intricate and difficult one. The forms for practically the entire ship must be placed before concreting starts. The accuracy of placing must be much greater than in ordinary building construction, for it the spacing is slightly oversized, it results in increased tare weight of the hull, which, of course, decreases the cargo capacity of the ship. The relatively high unit stresses and the small thickness of covering for the steel also requires unusual accuracy in placing the forms.

There are a number of ways of constructing the forms. They may be of wood or metal, or of wood lined with metal. It has also been suggested that plaster forms may be used. They may be built in panels or as one unit, to be later removed board by board. The inside forms may be first constructed, and the outside forms placed after the steel is fabricated. A more common method is to place the outside forms first, fabricate the steel, and then place the inside forms. The former method is being followed in the construction of one ship for the Emergency Fleet Corporation, but the latter method will be used on subsequent ships. Much time and money can be lost or saved in forming, and much thought and study can profitably be given to this work. In Norway there is one company building small craft by the so-called " upside down " method, in which the inside forms are fabricated in an inverted position. The concrete is shot into place with a gun, or applied by hand, a relatively stiff mixture being used. No ships are being built by this method in the United States.

REINFORCEMENT SMALL AND ACCURATELY PLACED.

Reinforcing steel which we are using, other than fabric, is of rods or bars rolled from new billets to conform to the American Society for Testing Materials standard specifications for structural grade new billet steel. Plain round bars will be much easier to fabricate than deformed bars, but on account of the uncertainty of the effect of reversal of stress we are using deformed bars wherever the bond stress is high.

The accurate bending of the reinforcing steel is one of the most difficult of all the construction problems. With a wall thickness of only 3½ in. to 4 in., and two to three layers of steel, need for accurate bending of the steel can be readily appreciated. Furthermore, the curvature is constantly changing forward and aft in the vessel, which requires constant change in the location of the dogs on the bending table. The use of small steel is recommended, in that it is easier to spring into place if the bending is not accurately done.

With a very large quantity of steel, approximately equivalent to 10 per cent. of the carrying capacity of the ship, to be placed in a very small space in thin walls, there is much opportunity for the development of ingenious methods of fabricating the steel. Undoubtedly much time can be saved by prefabricating, at least in part, the steel of the frames and placing them in the ship as units. These frames may be as much as 54 ft. in width and 35 ft. in height, and they must be accurate to within a fraction of an inch. Through a length of 60 per cent. of the ship the shape of these frames is constantly changing. All the steel must be supported and secured so that it will not touch the form surface. Numerous methods have been suggested, and there are a number of chairs now on the market for supporting steel, but all of them have objectionable features.

A study has been made of welding methods and machines as a means of avoiding the lapping of the steel. The acetylene weld is rather uncertain, and not satisfactory. The electric resistance weld appears to be the most promising. Several machines of this type have been ordered, and are now being tried out. The bond stresses are exceedingly low in the longitudinal steel, and there is more space available for lapping. In the frame steel, however, it is so close together that there is not room for lapping without increasing the thickness of some of the concrete members, which will in turn increase the tare weight of the hull. The weld by the electric resistance method can be made quite rapidly, and at small cost. It is not anticipated that welding any steel other than the main steel of the frames and possibly the main longitudinal steel will be required.

MIXING AND PLACING OF CONCRETE.

Rich mortar mixtures will be used, and they must be carefully proportioned and mixed in order to insure the quality of concrete necessary. Special attention should be given to the selection of the mixer, as all mixers of common types will not thoroughly mix mortars. The concrete should not be transported from the mixer and deposited directly into the forms in continuous operation or in large batches, on account of the danger of not having it thoroughly worked into place about the reinforcing steel. For the present it is required that all concrete shall be shovelled into the forms in order to insure its deposit in small batches and its thorough working into place.

The actual placing of the concrete is a small item in the cost of construction of a ship, and therefore there should not be the incentive to rush the work as in ordinary building construction.

It is preferable to place the concrete as one continuous operation in order to avoid construction joints. This will require approximately three days (of 24 hours each) for a 3,500-ton ship, and six days for a 7,500-ton ship. While it may appear difficult to work the concrete thoroughly around and through the reinforcing, no trouble is anticipated from this source. The rich mortar mixture proposed is quite fluid, even though it is not mixed to a wet consistency, and with a slight tapping of the forms it settles readily into place about the steel. A number of test panels have been made, and the results in all cases have been entirely satisfactory. It is very different to make a construction joint in a section in which is embedded a large quantity of steel. Most leakage troubles occur at construction joints. The uncertainty of the bond obtained at construction joints is also objectionable on account of the large shear stresses. Several mechanical methods of placing mortar and concrete have received consideration, but the results of investigations do not up to the present warrant their use.

TREATMENT OF HULL SURFACES.

It has been suggested by some that rough lumber be used for the outside forms, and a plaster coat be applied to the surface of the cast concrete. The application of such a plaster coat is not recommended, for the following reasons: The surface to be covered is very large, and the application of such a coat would have to be completed in a very short time. There is absolutely no way of assuring positively a perfect bond between the plaster coat and the concrete surface. The application of such a coat will increase the weight of the hull without compensating advantages.

Barnacles and sea vegetation will adhere to concrete in the same manner as they develop on steel and wood. It is therefore necessary that the bottom of the hull be coated with some anti-fouling paint. The same paints can be used as are now used on steel ships, except that special means must be taken to insure a thorough bond. Investigation of a number of paints and coatings of different types is now being made. It is quite probable for the present that a bituminous coating will be employed on the bottom of the Government ships.

LAUNCHING THE SHIPS.

There has been much discussion relative to the advantages and disadvantages of constructing the ship on ways which will permit of side-launching or end-launching. Ways built for side-launching permit of the construction of the ship on an even keel, thus making all the lines plumb. There have been very few accidents by sidewise launching of steel or wood ships, and it is believed the concrete ship can be safely launched somewhat earlier in this manner. In endwise launching the conditions of sagging or hogging depend upon the accurate positioning of the ways, and determination of the weight and conditions of buoyancy of the ship just before it leaves the ways. Slight settlement of any of the way piles may cause very serious hogging or sagging stresses. Two of the vessels being built by the Emergency Fleet Corporation will be launched endwise and the others will be launched sideways.

EQUIPMENT.

Certain of the equipment, such as the hawsepipe, stern frame, stern tube, etc., are cast into the concrete. The major portion of the equipment and all the machinery are secured to the concrete by anchor bolts. These must be accurately placed in the forms and completely detailed before the concrete is poured. Aside from the connections, the installation of machinery and equipment does not differ from the conditions met in either wood or steel ships. Wherever possible, through bolts rather than anchor bolts will be used. Under all deck machinery and fittings suitable waterproof gaskets should be placed so that there will be no leakage around the holding-down bolts. Too much attention cannot be given to the careful detailing of the fastenings and their exact location in the hull.

WHAT IS THE DURABILITY OF A CONCRETE SHIP.

If durability is to be obtained, special attention must be given to many elements of the ship. The most serious problems is to provide means of adequately protecting the steel from corrosion. There is a large quantity of steel embedded in the concrete, and much of it cannot be covered by more than ⅝-in. of mortar. This of itself will not protect the concrete, particularly in the interior and in the upper portions of the hull. There are two means of allaying, if not wholly preventing, the corrosion of the steel. The steel may be galvanised or painted with some protecting medium which will not appreciably affect the bond, or the concrete may be coated with some thoroughly impervious membrane which will prevent both air and water from reaching the steel. A large number of tests are being made, and it is quite possible both methods of protection will be tried. The results are promising, and a satisfactory protection should be developed.

Another possibly disintegrating element which may have great importance is the effect of constant reversal of stress, as the ship alternately is subjected to hogging and sagging stresses in a heavy sea. Our allowable steel stresses are such as to cause the concrete to crack. There are few analogous structures on land to which we can refer for guidance on this subject, and only experience can tell what may be expected. Reversal of stress tests are now under way.

No trouble from chemical disintegration is anticipated except as the hull may be seriously abraded.

The Concrete Ship Department estimates the life of the concrete ship without any special protection at several years, and known methods which can now be applied should extend the life several years longer. It believes adequate protection will be developed to insure reasonably permanent life to the concrete ship.

The use of direct current on a concrete ship should be avoided wherever possible, on account of the possibility of electrolysis from stray current. A very small leakage for an appreciable time, as demonstrated by the experiments of the Bureau of Standards, will cause a weakening of the mortar at the cathode, thus decreasing the bond strength. If the current leakage is large it may cause an oxidation of the steel at the anode, which will result in splitting and spalling of the concrete. The use of brass or bronze castings adjoining the concrete reinforcing should also receive consideration, on account of the possibility of local electrolytic action in the presence of the electrolyte.

With the quality of concrete being used no special provision will be needed to hold the heavier fuel oils. Investigations of various coating materials are being made with a view to their use as a lining if such is found desirable.

Sugar and certain vegetable oils, such as the cocoanut and peanut oil, will disintegrate the concrete if it is exposed for an appreciable length of time. If the ships are to be used in this class of trade, a protective paint coating should be applied to the inner surface of the hull.

The economy of the concrete ship cannot be determined until we have had experience over a term of years. The estimated cost of the concrete ship at the present time is approximately $125 per ton dead weight. The cost of a steel ship averages about $200 per ton, and that of a wood ship $165 per ton dead weight.

If proper coatings can be developed to prevent deterioration, the concrete ship should be a competitor of the steel ship. With further experience it is believed the weight of the concrete can be very materially reduced, thus making the cargo capacity more nearly equal to that of the steel ship.

GLEANINGS FROM THE ENEMY PRESS REGARDING CONCRETE AND REINFORCED CONCRETE.

It has been deemeed advisable that some particulars of the trend of enemy activities in technical matters should be known in this country. The following extracts and illustrations, taken from the Enemy Press, are partly from "Beton u. Eisen" and partly from other enemy papers, with the view of keeping our readers posted as to what is occurring in these matters.—ED.

PAVEMENT LIGHTS IN CONCRETE.

THE use of metal frames for the glass used in the construction of pavement and similar lights is accompanied by so many disadvantages that the substitution of concrete for the metal is a matter of considerable interest. According to a *brochure* recently issued by a Hungarian firm engaged in the manufacture of these lights, the concrete frames have exceeded all anticipations. As is well known, these lights are constructed of small squares of glass mounted uniformly in a framework (*Fig.* 1) in such a manner that they will not be damaged by traffic passing over them. It is essential that the upper surface of the arrangement shall be quite flat, the glass being flush with the frame; the undersurface is not subjected to any such limitation so long as an ample amount of light can pass through the whole. The concrete must, of course, be reinforced, and must be disposed so as to support the glass firmly whilst a maximum amount of concrete is used so as to reduce the amount of obscuration of light as much as possible.

One great advantage over a metal framework is that the concrete lights may be made on the site and so can be fitted accurately to any size of opening at a much less cost than if a special iron frame had to be made.

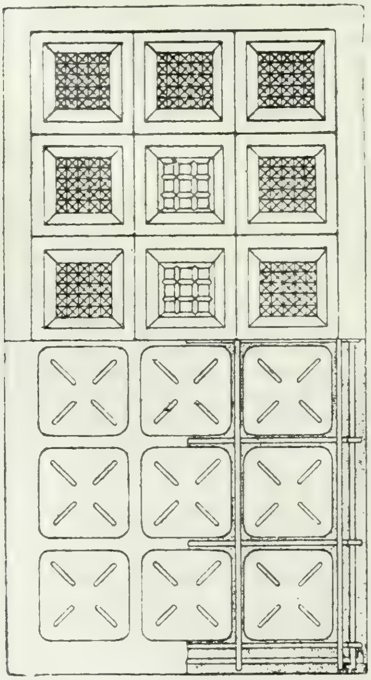


FIG. 1.

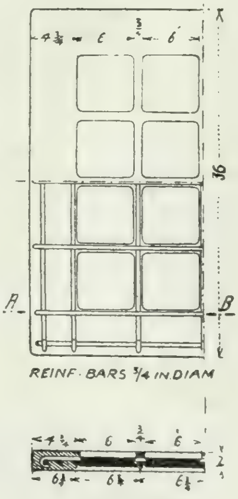


FIG. 2.

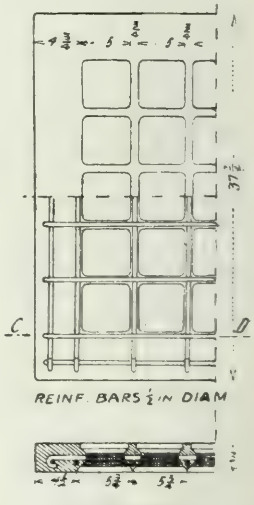


FIG. 3.

In order to test the strength of such framed lights, two of them—with glasses 2 in. and 3 in. thick respectively—were placed on the hollow bed of a testing machine so as leave a space of 32 in. between the supports, and were tested in such a manner as to show their strength when lying free, the condition being as similar as possible to those to which the lights are subjected when in common use. The results showed a high degree of elasticity, the permanent deformation under a load of two-thirds of the breaking strain being only 0·04 in., or 1-800th of the span. The first signs of cracking were observed under a pressure of one-third of the breaking strain for both sizes of glasses. The breaking strains under these conditions were found to be 0·6 tons per sq. ft. for the 2 in. and 1·7 tons per sq. ft. for the 3 in. glasses respectively.

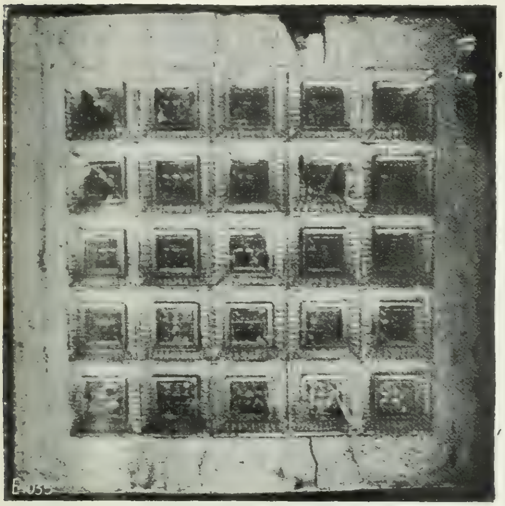


FIG. 4.

This test is defective in one respect, inasmuch as the frames were only supported in two places. Had they been supported on four sides, as they would be in ordinary use, the breaking strains would have been three times as great—namely, 1·8 and 5·1 tons per sq. ft. respectively.

It is interesting to note that, although patches of concrete became separated from the glasses whilst the tests were being made, yet the latter were so tightly held by the reinforcement that, even after the completion of the breaking test, they were still able to withstand more than half the breaking strain.

Figs. 4 & 5 show the upper and lower faces of a light after it had been broken in the testing machine. (*Beton u. Eisen.*)

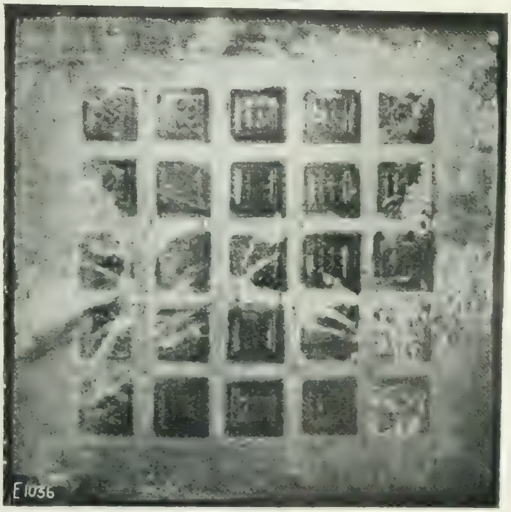


FIG. 5.

LIGHT-WEIGHT REINFORCED CONCRETE SHIPS.

According to the *Deutsche Bauzeitung* of February 23rd, Messrs. Rüdiger of Hamburg claim to have invented a special concrete for the making of concrete ships. They state that this concrete weighs only half that of the usual concrete made with gravel. The concrete is composed of four different materials and its specific gravity is only 1·03 to 1·25. It is stated to be tougher and more elastic than ordinary concrete and 30 cm. cubes have an ultimate strength in compression of 180 to 200 kg. per sq. cm.

Vessels can be built of this material which weigh no more than vessels of similar capacity made of steel, while the steel reinforcement weighs only 15 per cent. to 20 per cent. of the metal used in a steel ship.

A RUSSIAN WATER-TOWER.—RESISTANCE TO SHOCK.

An interesting example of the enormous power of resistance to shock is shown in the three accompanying illustrations from *Beton u. Eisen* of a concrete water-tower to which explosives had been applied to all except two of its supports by the Russians during a retreat. A careful investigation showed that the tank was not so *seriously* damaged as the illustrations appear to indicate, as the large pieces which have flaked off are only the outer coating or insulating wall. The tank itself had only a few insignificant cracks which could readily be repaired.

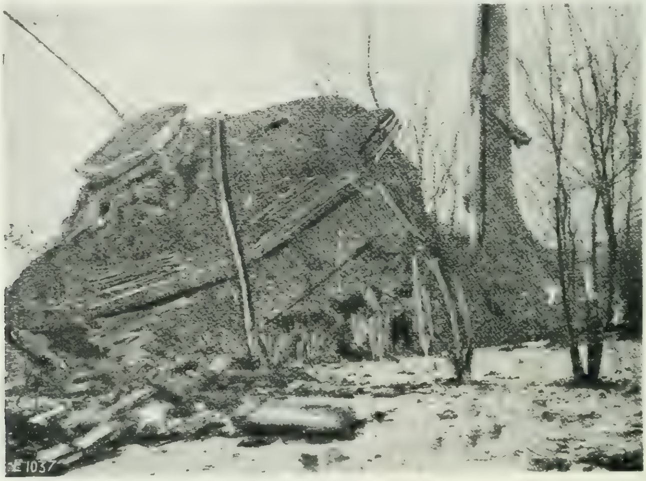


FIG. 1.

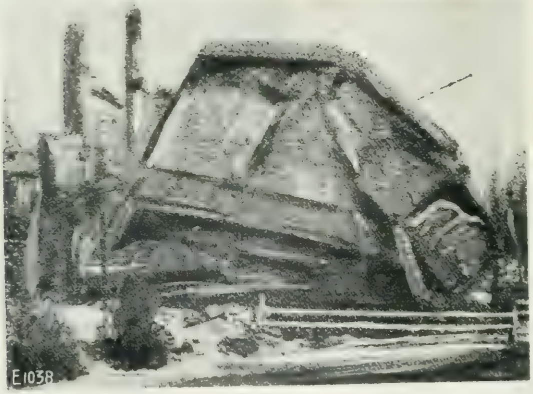


FIG. 2.

NEW WATER TOWER FOR ENGINEERING WORKS IN SILESIA.

The *Deutsche Bauzeitung*, June 15th, contains an illustrated article dealing with a reinforced concrete water tower recently completed for some large works in Silesia. The tower comprises a reservoir containing 2,000 cu. m. at a height 31 m. above the ground. There is a drinking-water reservoir below the main reservoir of 150 cu. m. capacity, and on the ground floor an ozonising reservoir of 150 cu. m. capacity, making the total storage capacity of the tower 507,610 gallons.

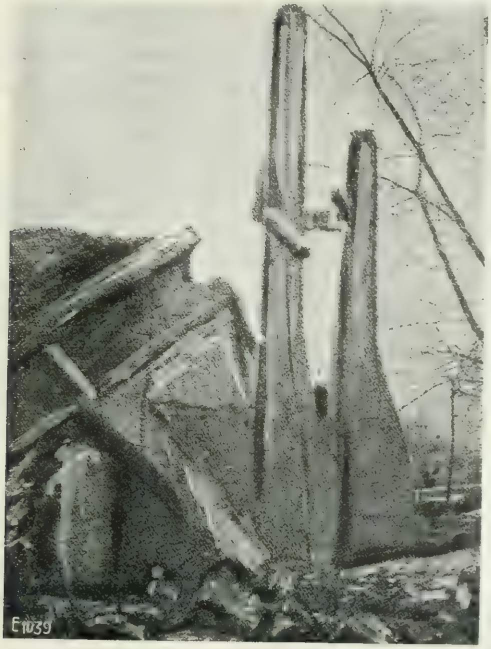


Fig. 3.

REINFORCED CORK BLOCK WORKS AND RESERVOIR.

The Supplement of the *Deutsche Bauzeitung*, January, 1918, contains an illustrated article describing the method employed in building a factory for the production of cork stone blocks at Ludwigshafen on the Rhine. The building is entirely of reinforced concrete, the special feature being that the cork stone blocks are laid direct upon the beams of the structure and below the concrete platform in order to render the building less resonant. This method appears to have proved successful.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Press Supplements on Economy and Reconstruction Questions in Foreign Countries.—All firms who desire to know what their rivals are doing and planning—notably those in enemy States—and what are the economic conditions and trading prospects in foreign countries can now obtain two valuable War Office publications, issued fortnightly, the Economic and the Reconstruction Supplements to the *Daily Review of the Foreign Press.* The price of these Supplements will be 6d. The Economic Supplement deals with trade and commerce, railways and shipping, banking and finance, labour conditions, social and economic policy and legislation, etc. The Reconstruction Supplement describes the measures being taken or suggested in Germany and elsewhere in connection with the return to peace conditions.

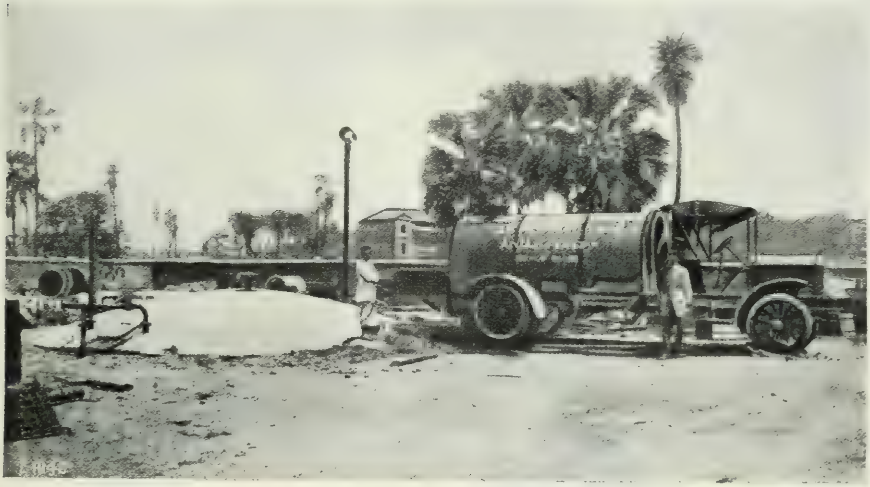
Half-yearly Indexes to the above, price 6d., can also be obtained.

These publications will be issued by His Majesty's Stationery Office, and can be purchased through any bookseller or directly from H.M. Stationery Office at the following addresses: Imperial House, Kingsway, London, W.C.2, and 28, Abingdon Street, London, S.W.1; 37, Peter Street, Manchester; 1, St. Andrew's Crescent, Cardiff; 23, Forth Street, Edinburgh; or from E. Ponsonby, Ltd., 116, Grafton Street, Dublin.

The Concrete Institute.—(*Session* 1918–19). We have received an early copy of the provisional programme of the Concrete Institute for the coming session. The programme (which is subject to revision) is as follows:—November 28th, 1918, Presidential Address, by H. D. Searles-Wood, F.R.I.B.A.; December 19th, "Æsthetic Design in Reinforced Concrete," by C. F. A. Voysey, A.R.I.B.A. January 23rd, 1919, "Corrugated Sheeting," by N. Noel Ridley, M.Inst.C.E.; February 27th, "Industrial Safety First," by E. Willis, Assoc.M.Inst.C.E.; March 27th, "Ferro-Concrete Ships" (lantern), by J. S. E. de Vesian; April 24th, "Steel-framed Sheds," by A. R. Spencer; May 22nd, Tenth Annual General Meeting; Paper on "Aggregates," (lantern), Professor P. G. H. Boswell.

Concrete and Housing. At the recent sectional meeting of the Royal Sanitary Institute, held at the Town Hall, Ipswich, Sir Henry Tanner, C.B., I.S.O., read a paper on "Housing from the Point of view of Economy in Planning and Construction." Dealing with the subject of materials the author stated that all floors, too, should be of concrete or composition, especially now that wood was so expensive, whilst so far as possible wood joists should be replaced by reinforced concrete or hollow tile beams. Lath and plaster partitions should be avoided, and replaced by slabs, concrete, or half brick. The aim should be, generally, so to construct the houses as to avoid waste of space, complicated construction, breaks in walls, involving valleys or hips to the roofs, more walling, etc., to enclose a given area, but at the same time it was not economy to scamp either materials or workmanship at the cost of increased expense in maintenance, for the cost of repairs would be probably much greater than the small additional expense which would have been originally needed to avoid the liability.

Reinforced Concrete Oil Tanks in India.—Owing to the shortage of coal many of the Bombay mills have resorted to liquid fuel. Up to the present oil tanks have been built in India of mild steel plates, but owing to the difficulty of obtaining this material, combined with its high price, many leading engineers have recognised the advantages of reinforced concrete. A large number of such tanks have been built by Messrs. Marsland, Price & Co., Ltd., Bombay, for different mills. These tanks have been in operation for some time, and have proved very successful. The accompanying illustration shows a reinforced concrete liquid fuel tank built by the above firm in the compound of the Jacob Sassoon Mill, at one of the largest mills in India. The tank is 150-tons capacity, 25 ft. 6 in. diameter. The total depth of oil being 12 ft. The view shows an oil tank mounted on a motor delivering oil into the tank.



CONCRETE OIL TANK IN INDIA.

Concrete Oil Tanks.—Reinforced concrete instead of steel is being used in the Panama Canal Zone in constructing oil tanks for use on the Isthmus. The first of the new storage tanks is now being built at Mount Hope. It will have a capacity of 55,000 barrels.

The Concrete Age.—In his review of the National shipbuilding position in the House of Commons, Sir Eric Geddes paid a well-deserved tribute to the concrete system which has solved the building difficulty in countless undertakings for the Government since the beginning of the war. "On the Wye," he said, in dealing with the national shipyards, "we are building houses of an admirable but most economical type. I am assured by the engineer-in-charge that the system of concrete blocks employed is actually cheaper to-day than woodwork or corrugated iron huts." Concrete blocks and slabs, indeed, with our rapidly diminishing supplies of timber, bricks, and other materials, are coming to the front by leaps and bounds in every branch of structural war work, and must, of necessity, play a leading part in all schemes of reconstruction both at home and abroad. It is interesting to learn that the work referred to by Sir Eric Geddes is being carried out on the "Winget" system, the blocks and slabs of which are now being used for 80 to 90 per cent. of the present camps, hangars, and housing schemes, etc., as specified by the Admiralty, War Office, and other Government Departments of Great Britain and her Allies.

Concrete Rolling Stock.—We learn that some interesting experiments are now being made at the works of the Ebbw Vale Steel, Iron and Coal Co., Ltd., in the direction of the construction of railway wagons of reinforced concrete. At the present time the project is quite on experimental lines, but already wagons have been made of reinforced concrete, and have passed tests such as to warrant the highest expectations that rolling stock will be turned out at a later stage at lower cost and equal in durability to existing rolling stock.

The BRITISH STEEL PILING Co

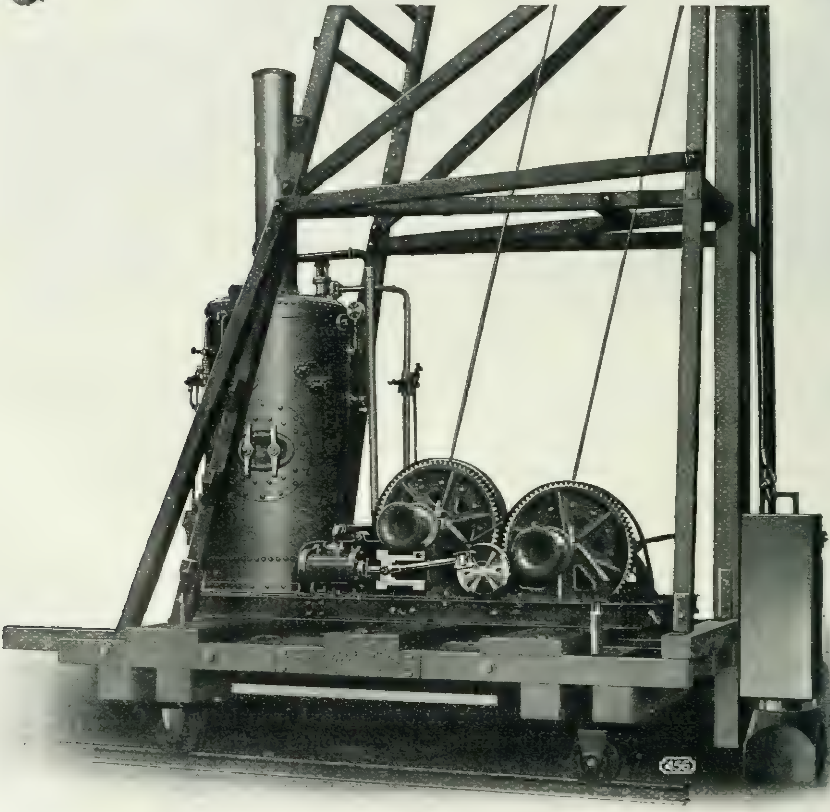


Illustration shows "Zenith" Friction Winch mounted on Pile Driving Frame. Send for catalogue.

DOCK HOUSE, Billiter Street, LONDON, E.C.

Large Concrete Piers.—In connection with the construction of the Philadelphia Dry Dock, we learn that there are to be three double-deck steel, concrete, and timber piers, 1,300 ft. long and 150 ft. wide, together with a lighterage pier of 1,350 ft. by 75 ft. one storey high. The piers will be larger than any existing in New York harbour at the present time, and will accommodate the biggest ship afloat.

Lava Rock as an Aggregate for Concrete Ships.—In a letter written to *Concrete*, U.S.A., Capt. Frank Whipperman states that he is convinced that lava rock should form an excellent aggregate for certain forms of concrete construction where lightness, combined with great strength, are essential, as, for example, floors and ships. He has made a certain number of tests for hardness, etc., and according to his experience this lava rock, found by him in the desert, is the hardest rock he has come across. Capt. Whipperman was unable to complete his tests, but he says in his letter that he " is satisfied that concrete made with this aggregate would be 50 per cent. lighter than any other suitable aggregate. With proper crushers it could be reduced to 1½ in. to ¾ in., and there would be enough of the rock crushed finer so that no other aggregate in the way of sand would be needed. There would be very little dust." According to the writer there are thousands of acres of this rock on the top of the ground and near to the railroad tracks in New Mexico, and there are probably other lava beds in the United States.

Cementation applied to Mining.—An interesting paper on this subject was recently read by Mr. A. N. Kryssand before the Chemical, Metallurgical, and Mining Society of South Africa. The author dwelt on the value of this process for various mining structures, and said that cementation has been successfully applied to mining in the following instances :

1. In greatly minimising water difficulties in shaft sinking or tunnelling through water-bearing strata, faults, and dikes.
2. In sealing and rendering water-tight the concrete tubbing or lining often used in circular shafts.
3. In sealing open fissures through which water is flowing.
4. In damming back water leaking through broken ground in the vicinity of faults and dikes.
5. In rendering underground dams water-tight.
6. In rectifying defective boreholes.
7. In rendering impervious the foundations of surface dams or making solid the rock and concrete foundations of engines, etc. The author cited numerous instances in South Africa mining where the process has been applied, and the paper was also well illustrated.

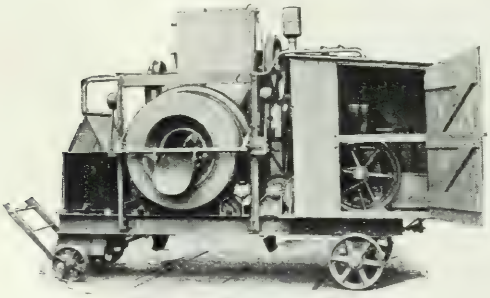
Concrete Stone Masonry.—The accompanying illustration is a recent example of concrete stone masonry as carried out in the north by the Stockton Stone Concrete Co., Ltd., of Morton, near Stockton-on-Tees.

YARM LANE SCHOOL.

Reinforced Concrete Flat Slab Construction.—At the Convention of the American Concrete Institute, Mr. A. B. Cohen, Assist. Engineer-in-Charge Concrete Design, of the Delaware, Lackawanna, and Western Railroad, Hoboken, N.J., read a paper on Reinforced Concrete Flat Slab Railway Bridges. Mr. Cohen claims many advantages for this form of construction as compared with other methods, and in support of his arguments gave a number of well-illustrated examples of work carried out in the United States.

Road Bridge over the Reuss, near Gisikon, Switzerland.—The *Schweizerische Banzeitung*, July 6th, states that, as the result of a competition to obtain designs for a road bridge over the Reuss, the first prize was awarded to the design of a reinforced concrete bridge of single span 210 ft. long and having a total width of 24·6 ft.

A Concrete Barge Launched at a South Coast Port.—As we go to press we learn that a 1000-ton reinforced concrete barge was launched on August 24th at a south coast port. The barge was designed by Mr. E. C. Williams, of the Marine and General Concrete Construction Co., and built by Messrs. Hill, Richards & Co., and has a length of 190 ft., a beam of 33 ft., and a moulded depth of 15 ft. 6 in. When loaded the vessel's draught will be 12 ft. In a later issue we hope to make further reference to this barge.



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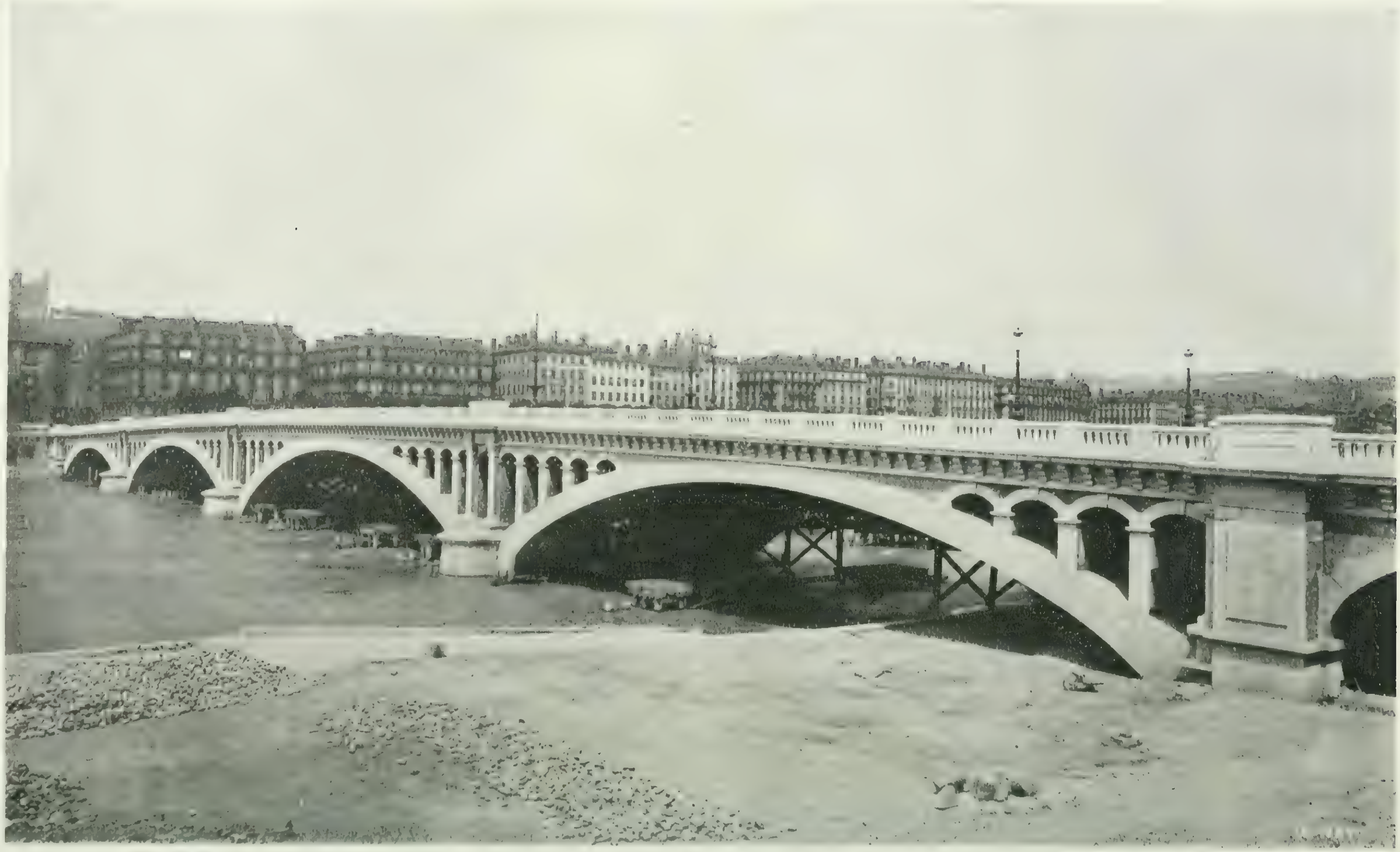

THE WILSON BRIDGE, LYONS.
(For Description see page 520)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIII. No. 10. LONDON, OCTOBER, 1918.

EDITORIAL NOTES.

RESEARCH.

WE have before us a very interesting report of the Committee of the Privy Council for Scientific and Industrial Research for the year ending July 1st, 1918.

The report does the greatest credit to the Committee of the Privy Council, but also very particularly to the Advisory Council, of which Sir William McCormick is the administrative chairman and Sir Frank Heath is secretary.

It is most satisfactory to see the steps which have been taken to encourage research, especially among the various industries where systematic investigation has been much neglected.

The idea of forming associations, within those industries to be assisted financially from a special fund at the disposal of the Committee of the Privy Council, bids fair to work most advantageously in the majority of cases, and we are interested to observe that among the various industries in which associations are being formed on these lines is the Portland Cement industry.

There is naturally a certain fear among the industries concerned that any connection with a Government department may lead to undue restrictions and the like, and for this reason we believe certain associations are being formed on the lines of those recommended by the Committee of the Privy Council, but without official representation or financial assistance.

If an industry really feels so strongly on this matter of State interference and has the funds to carry on its own research work systematically and well there is little to say against the formation of independent associations, except that they may lose the opportunity of receiving valuable guidance and information from H.M. Research Department, and that there may be wasteful overlapping as between the investigations inaugurated by the free-lance associations and what we would term the controlled associations. Probably everything will now depend upon the extent to which the Committee of the Privy Council will use their powers when financing new associations as to whether controlled associations will become a popular factor in industrial research, but we see no reason why anything but cordial encouragement, combined with tactful supervision, is to be expected, and thus look forward to a rapid development of this excellent form of State aid. There is, to our mind, a vast field for these controlled associations in almost every industry, and the Committee of the Privy Council have fortunately ample funds to support a considerable number of such associations for the next few years.

The funds for this particular purpose, it should be remembered, come from a special grant of one million sterling voted by Parliament, which is apparently to be applied only to research where the industries are able to contribute substantially to the object in view.

Turning to another aspect of the activities of the Committee of the Privy Council, namely the support accorded to professional bodies and individual investigators to undertake particular forms of research, we note with great pleasure that Housing Research is being supported, and that there are certain investigations being undertaken into the question of building materials. Not least in importance among these enquiries, we imagine, are the investigations which are being undertaken as to the fire-resisting properties of concrete. It is to be regretted, however, that those who were investigating certain aspects regarding the strength of concrete made of different local aggregates have had to suspend their efforts during the war ; the plan of transferring certain sections of this enquiry to a number of universities and colleges having apparently not been a success under present-day conditions.

There is a vast amount of research work still required on problems of concrete and reinforced concrete, and though, at first sight, the endeavours in this direction may appear somewhat limited in scope, it is not unlikely that experiments under the broad heading of fire resistance will have considerable bearing on the world's knowledge of concrete and reinforced concrete construction generally. Every encouragement should, accordingly, be given to this particular investigation, as the effect of high temperatures upon concrete is likely to afford important lessons on structural problems of the widest range.

Here we would remark that it would seem curious that any financial assistance accorded to professional bodies for matters of research of this kind apparently would have to come from annual Votes in small amounts, whilst the financing of the great industrial associations, as indicated before, comes out of a special Grant. We feel that a similar grant as that at the disposal of the associations should be available for the research of the professional bodies, the allocation being in the hands of the Committee of the Privy Council, and not subject year by year to the ups and downs of parliamentary expediency. Whether this could be best done by allowing a proportion up to, say, one-third of the existing grant for the purposes of the associations to be also applied to professional research is a matter that requires consideration, but what would probably be best would be to form a second fund to cover the many important researches initiated by the professional societies, not least among which, to our mind, is the investigation on concrete in sea water.

It should be clearly understood that not only on the industrial side, but on the professional side this country has to make up vast leeway in research, and given the necessary funds and a control that weighs lightly upon the various professional institutions which comprise men who are used to working independently, the splendid start made by the Committee of the Privy Council should within the next decade give us true research and values quite incalculable in comparison with the sums so far voted or to be expected at the hands of Parliament.

It is to be hoped that the endeavours of the Committee of the Privy Council will have the enthusiastic and keen support of all professional bodies.

CONCRETE SHIPS AND BARGES.

Lord Pirrie, one of the world's most successful shipbuilders, recently found, upon taking office, that considerable headway had been made with the production of concrete barges, but appears to have been disappointed with the amount of skilled labour required in producing this form of tonnage. Although an out-and-out steel tonnage specialist, Lord Pirrie will be well advised not to let his enthusiasm for steel tonnage, of which he has had close on sixty years of experience, prejudice him against concrete tonnage, of which the country has, so far, had scarcely six months' experience. If he will apply his experience to devising means of economising skilled labour and applying the modern practice to what is now largely the experimental stage of concrete shipbuilding, we have no doubt this new industry would benefit from his advice, and eventually much labour, time and material would be saved.

Leaving aside the question of large sea-going vessels one thing is an absolute certainty, and that is that *the concrete barge has come to stay*, and the only point that arises is how to make these barges thoroughly water-tight, how to overcome any question of expansion, and how to turn out these barges as repetition work with the least possible amount of timber for scaffolding and forms.

To put difficulties in the way of the development of the concrete barge would be regrettable. What is wanted is the best advice and every possible facility. Such difficulties as exist are largely due to the somewhat curious way in which the original contracts for concrete barges were let, the lack of consultation between the leading reinforced concrete engineers and contractors, and the absence of a well-organised official centre to deal with the subject on national lines irrespective of any individual interests.

The Admiralty might well take a leaf out of the book of our American colleagues in this direction, for in the United States practically everybody who counts was first consulted on the subject. Further, in order to bring home to the "powers that be" the results of such consultations, we reprint the body of a letter addressed to the United States Shipping Board on April 5th, by the Chief Engineer of its Department of Concrete Ship Construction, which will be found among the official papers recently published as a "Senate Document." This important letter reads as follows :—

AN AMERICAN GOVERNMENT REPORT.*

"The organisation of the concrete ship department has sought all available information of whatever reliable source that would bear upon the strength, the durability, and the seaworthiness of the material and of the structure as a whole. It has been in constant touch with the two largest registration societies and with various departments of the Government, within whose jurisdiction fall the operation, inspection, and repair of all classes of seagoing and waterway craft. It has brought together the opinions of recognised naval architectural authorities, of investigators in concrete and structural engineering, and the best practice in design and construction of reinforced concrete structures. It has consulted many recognised specialists in various fields relating directly or indirectly to the problems under consideration. It has blended all of the facts obtainable from these sources into the development of the concrete ship."

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*Published in Washington under Senate Resolution, No. 20[illegible], of June 17th, 1918.

" Following is a summary of our conclusions :

" 1. The reinforced concrete ship can be built structurally equal to any steel ship.

" 2. The available information assures with all the certainty possible, short of actual experience under service conditions, that the concrete ship will be durable for several years, assuring satisfactory service throughout the probable duration of the present war.

" 3. The cost of the reinforced concrete ship complete will vary between $100 and $125 per ton deadweight, depending upon the number of ships built and the conditions of construction. The cost of the hull only will be between $30 and $40 per ton deadweight.

" 4. The construction of concrete hulls will not interfere with the present programme for the construction of steel and wood hulls, in so far as labour or materials are concerned.

" 5. The concrete ship department has completed the detailed plans for a 5,500-ton concrete ship, so that construction of such ships can start immediately.

" 6. We estimate that between 150 and 200 3,500-ton concrete hulls can, if we start immediately, be completed by December 31st, 1918 (total approximately 600,000 tons).

" 7. We further estimate, if the construction of yards is begun immediately, and the construction of hulls of 7,500 tons each commences by June, 1918, 250 can be completed by August, 1919."

" We believe that we can exceed the above estimates in case it is found that the necessary machinery can be provided.

" Assuming that the above programme, which involves the immediate construction of 20 yards with 7 ways each, is started at once, even if for any reason the concrete programme should be abandoned after several ships had been given a thorough trial, the actual loss to the Government occasioned by the loss of labour and materials for both ways and ships under construction would not exceed $9,000,000."

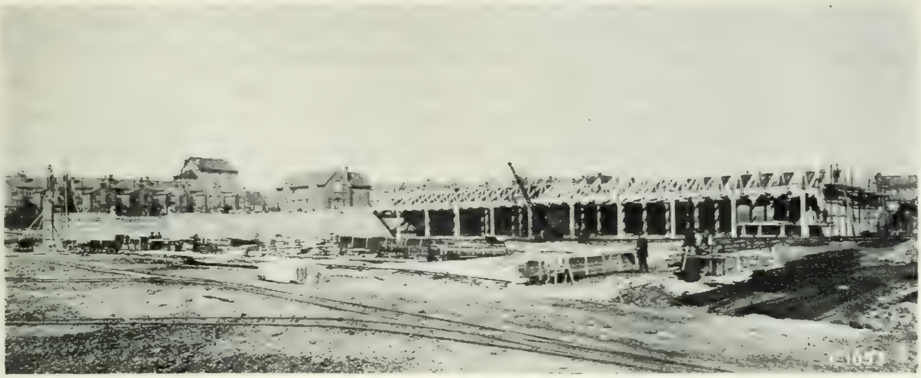

Fig. 1. General View during Erection.

REINFORCED CONCRETE FACTORY, BIRMINGHAM.

By ALBERT LAKEMAN, M.S.A.

The new factory which is now under construction for the Birmingham Small Arms Co., Ltd., contains some interesting points in pre-cast concrete construction, and it forms a typical example of what may be described as a war-time structure.—ED.

PRE-CAST CONCRETE.

PRE-CAST concrete has become very general during the past twelve months and considerable developments have taken place as a result of the experience gained. Several reasons have been responsible for its use in the first instance, and the chief of these has been the need of conserving the timber supply by practising strict economy in all building work. At the same time it has been essential to reduce the use of steel to the absolute minimum, and in consequence it became necessary to adopt reinforced concrete wherever possible, but the shuttering had to be very limited. Added to these factors is the necessity for speedy erection and it is a well-known fact that for concrete work *in situ* a large amount of shuttering must be provided if the execution is to be of a continuous nature, as it is impossible to wait several days, and sometimes weeks, for the shuttering at one point to be taken down and re-erected where required. When pre-cast units are employed the moulding of the concrete can be commenced immediately and be proceeded with during the whole of the period required for excavation, levelling and site work generally, and the forms used can be simple and capable of re-use for a large number of members of the same size. Again, as the work is done at the ground level, the placing of the reinforcement and concrete is greatly simplified and supervision is very easy. In the case of roof trusses it will be obvious that the advantages of casting the member on the ground are tremendous, as the difficulty of shuttering and propping during placing of the concrete *in situ* can only be overcome by the use of a large amount of timber and scaffolding generally and the resulting mixture is of a more uniform nature when cast on the ground, as tamping is easier.

CONSTRUCTION OF BUILDING.

The building under erection is of the single storey workshop type, with north light roof trusses, and it is 640 ft. long and 200 ft. wide, while the height to the underside of the tie-beam is 14 ft. 3 in. The columns are spaced to give bays 20 ft. square, with the exception of a portion near the centre of the building, where a clear width of 40 ft. is given for a crane bay which crosses the full width of the structure. A railway siding enters the building and is carried through, so that any heavy goods can be loaded or unloaded by the crane under cover and in a convenient position for handling to the machines in the shop which is adjacent. The same railway siding is also arranged to pass over the coal bunkers of the boiler house in order to discharge the fuel directly to the point required.

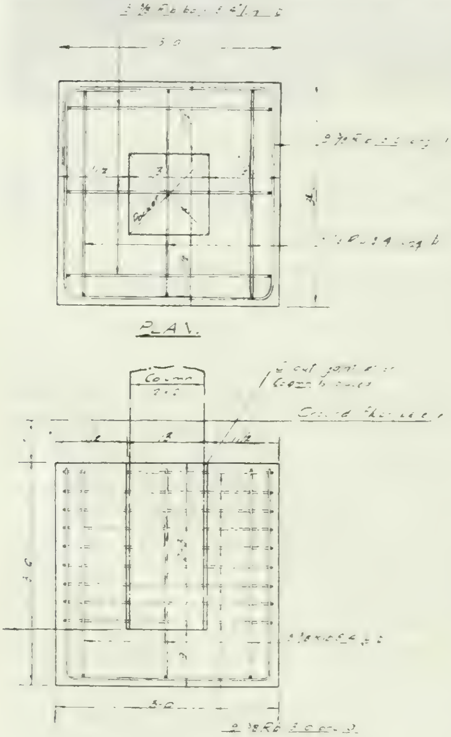

Fig. 2. Typical Column Base.
A Reinforced Concrete Factory, Birmingham.

Columns.—The column foundations are being cast *in situ,* as no advantage is gained by pre-casting these portions of the work, and they are 3 ft. square on plan and 3 ft. deep, with the undersurface at a level of 3 ft. 7 in. below the floor line.

The reinforcement consists of $\frac{3}{8}$-in. rib bars, which run across the bottom and up the sides at several points, and outside these are other $\frac{3}{8}$-in. rib bars arranged horizontally around the outer surfaces of the base.

As the columns are pre-cast it was necessary to make provision for the connection to the base, and this was achieved by forming a pocket in the base, which is 13 in. square and 2 ft. 3 in. deep. As the columns are 12 in. square, a space of $\frac{1}{2}$ in. is left all round, which is grouted up after the work is in position, and thus a good joint is obtained. In the case of the stanchions to the crane bay a different type was used, as the work at this point was cast *in situ,* and thus no pocket was required to receive the columns. These bases are 8 ft. by 3 ft., with a splay on the two long sides from a minimum thickness of 12 in. to the point of intersection with the column, where the thickness is 2 ft. The columns which support the crane girders are 24 in. by 14 in., reinforced with eight lines of vertical rods. The base is reinforced with $\frac{3}{8}$ in. and $\frac{5}{8}$ in. rib bars on the lower surface, and $\frac{3}{4}$ in. rib splice bars were left projecting above the base to provide for the attachment of the column bars. The foundations generally were designed to give a maximum pressure on the soil of $2\frac{3}{4}$ tons per sq. ft. A detail of a typical base for a pre-cast

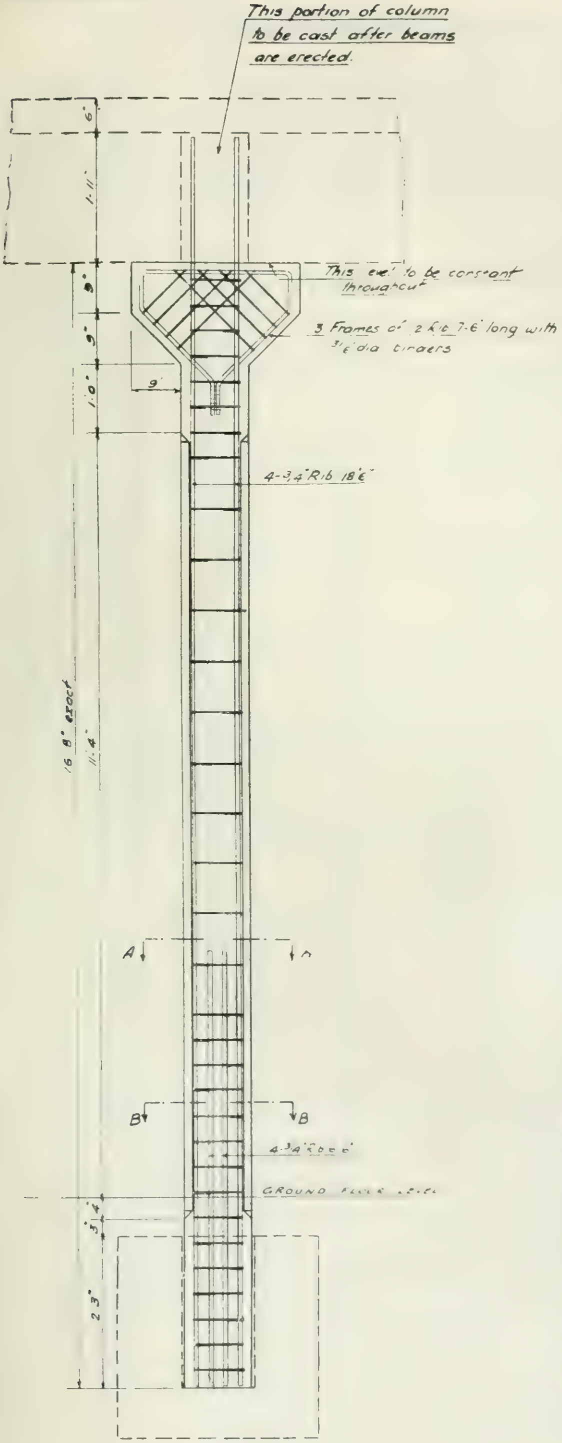
This portion of column to be cast after beams are erected.
6"
1-11"
This level to be constant throughout
3 Frames of 2 Rib 7-6" long with 3/16" dia binders
9"
9"
9"
1.0"
4-3/4" Rib 18'6"
16'8" erect
11.4"
A
A
B
B
GROUND FLOOR LEVEL
3'4"
2'3"

Fig. 3. A Typical Column.
A Reinforced Concrete Factory, Birmingham.

column is illustrated in *Fig.* 2. The ordinary columns are 12 in. square, and the reinforcement consists of eight $\frac{3}{4}$ in. rib bars in the lower portion and four $\frac{3}{4}$ in. bars in the upper portion, with $\frac{3}{16}$ in. dia. binders at $4\frac{1}{2}$ in. and 9 in. centres. At the head of the column a bracket having a projection of 9 in. on each of two sides is provided to give a seating for the precast beams, which in turn support the trusses, and these brackets have a total depth of 18 in., with $\frac{1}{2}$ in. rib bars as reinforcement, bent to shape with the ends carried down into the core of the column and well wired together.

In addition, $\frac{3}{16}$ in diam. binders are taken round these rods at right angles to the splayed surface of the bracket, and carried up to the top of the column. The four bars which act as reinforcement to the upper part of the column are arranged to extend about 1 ft. 10 in. above the head of the column, and these are left exposed until the beams resting on the brackets are in position, these beams being so arranged that there is a space between the ends of about 12 in. over the column, into which the column rods pass. When the beams and columns are in the correct positions in the building the space is filled in with concrete, thus tying the parts together with the assistance of the projecting rods. The wall columns are of similar size and type, with the exception that

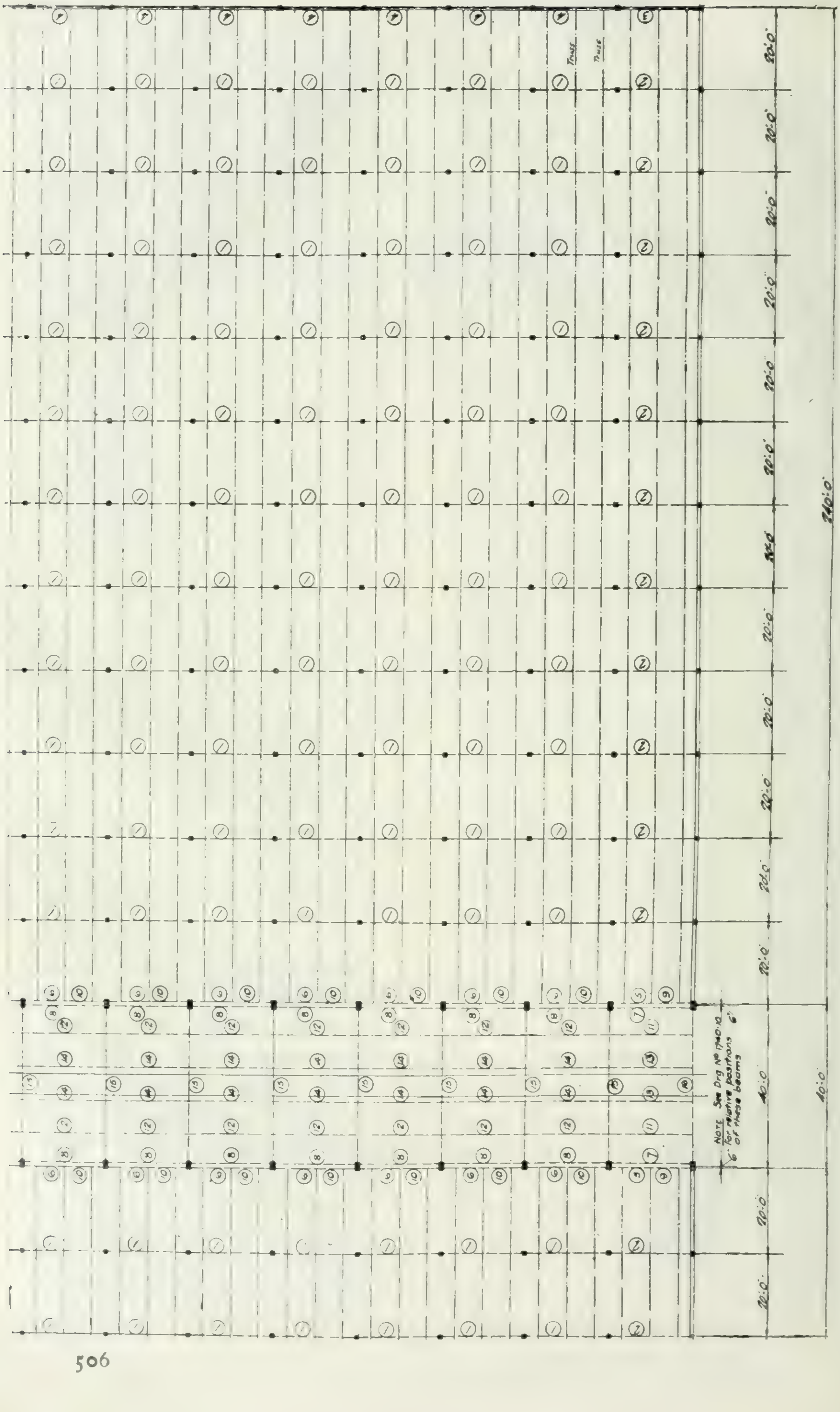
Truss
Truss
20'0"
240'0"
40'0"
Note. See Drg No 1740/12 for relative positions of these beams
6"

Fig. 4. Part Plan

A Reinforced Concrete Factory Birmingham.

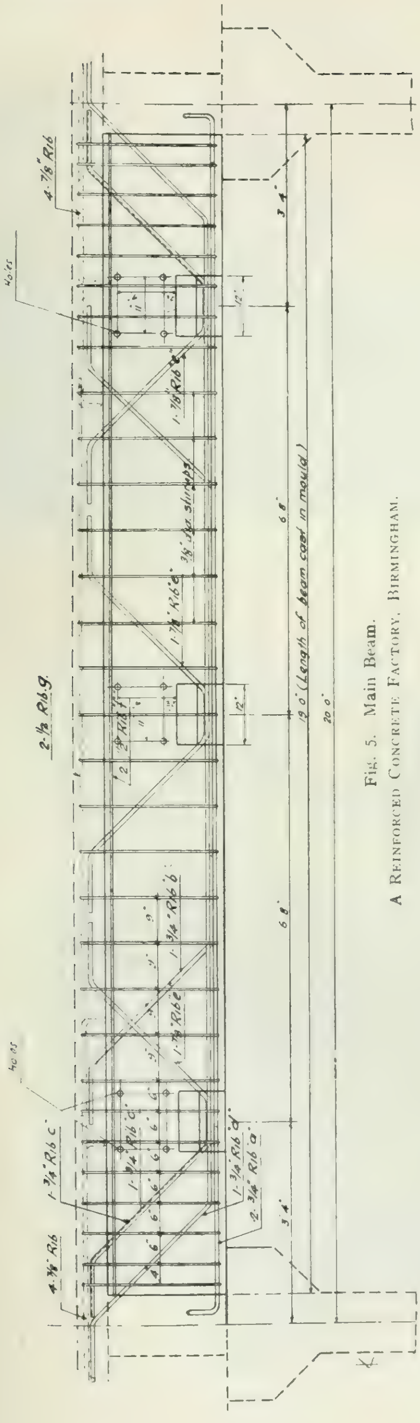

Fig. 5. Main Beam.
A Reinforced Concrete Factory, Birmingham.

a bracket was required at the head on one side only.

Beams.—One of the most difficult features in pre-cast work is that of the valley beams which rest on the columns and support the ends of the trusses, as it is necessary to provide continuity of the roof covering at this point and avoid any joint between the beam and the roof slope; while the top portion of the beam which actually forms part of the gutter between two adjacent slopes cannot be formed of a greater width than the lower part of the beam on account of the need of lowering the trusses into position. To overcome this difficulty the lower portion of the beams only were pre-cast and the remainder was formed *in situ* at the same time as the main roof covering, and a monolithic structure was obtained by leaving the upturned beam rods and the stirrups projecting above the pre-cast work to form a bond with the concrete placed *in situ*. The total depth of the beams when completed is 2 ft. 6 in., and of this a portion about 2 ft. deep was pre-cast As previously stated, the distance between the column centres is 20 ft., and the length of the beam as cast in the mould is 19 ft., this giving the space of 12 in. over the head of the columns and between the ends of the beams, which was filled in with concrete after erection. The beam rods were also left projecting, so as to enter this *in situ* concrete, and thus a good connection is obtained between the columns, beams and roof concrete. The main beam reinforcement consists of five ¾ in. rib bars in the lower surface, of which three are cranked up toward the ends, and these were left protruding to form a bond with the top portion, which was formed later. The reinforcement in the upper surface over the column consists of four ⅞ in. rib bars, and these, of course, come within the concrete placed after the beam

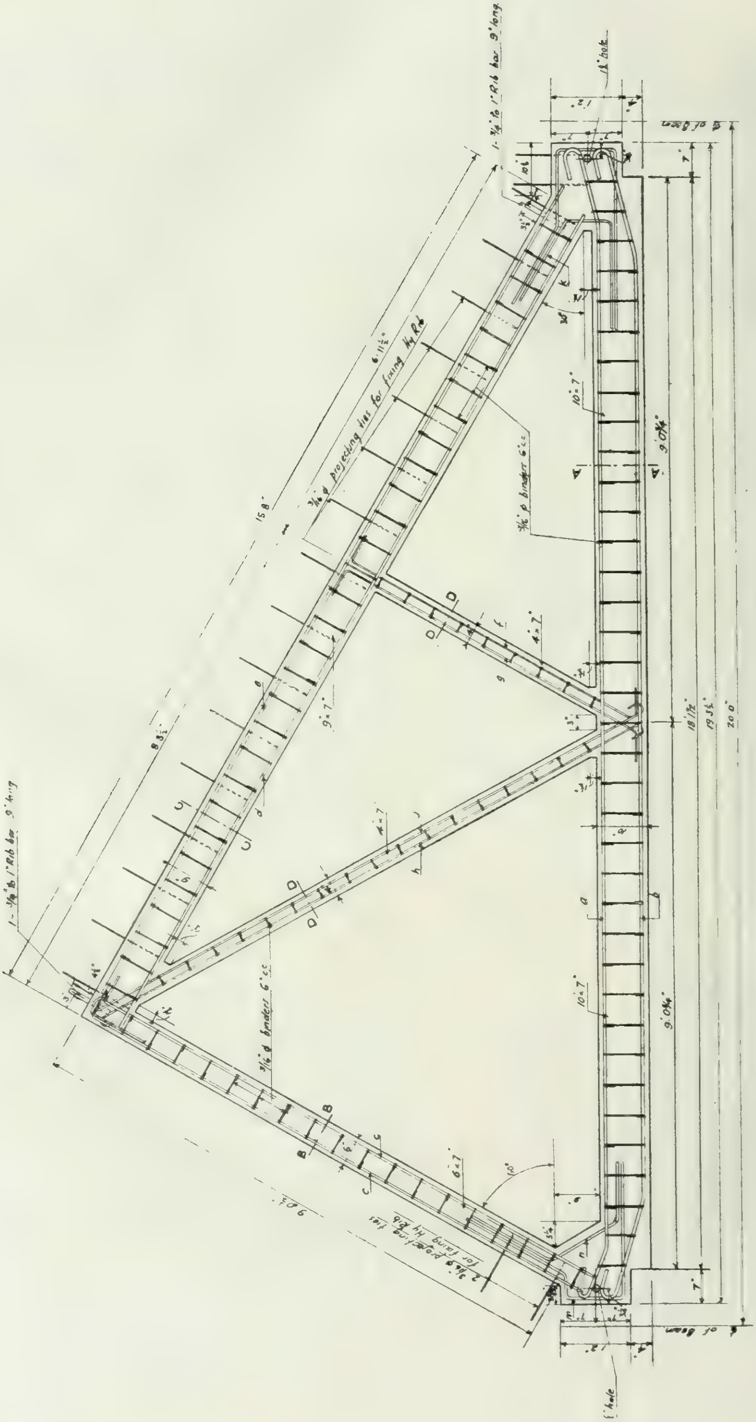

Fig. 6. Elevation of Truss.
A Reinforced Concrete Factory, Birmingham.

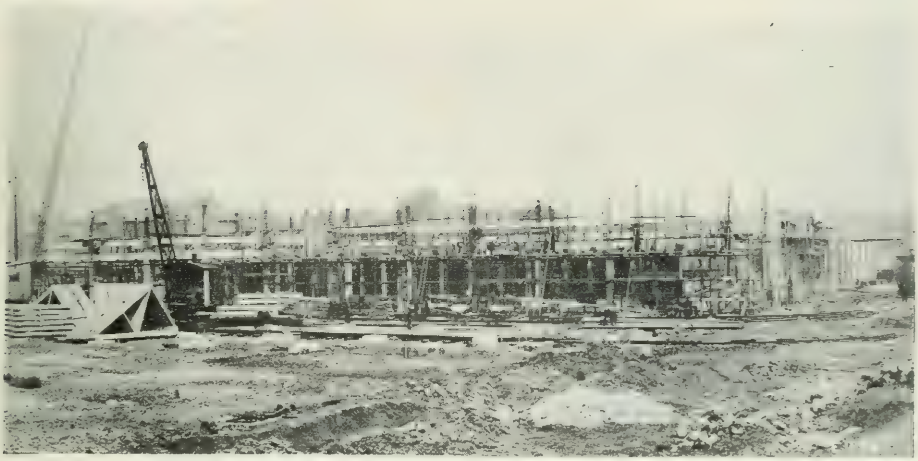

Fig. 7. View showing erection of Crane Bay.
A Reinforced Concrete Factory, Birmingham.

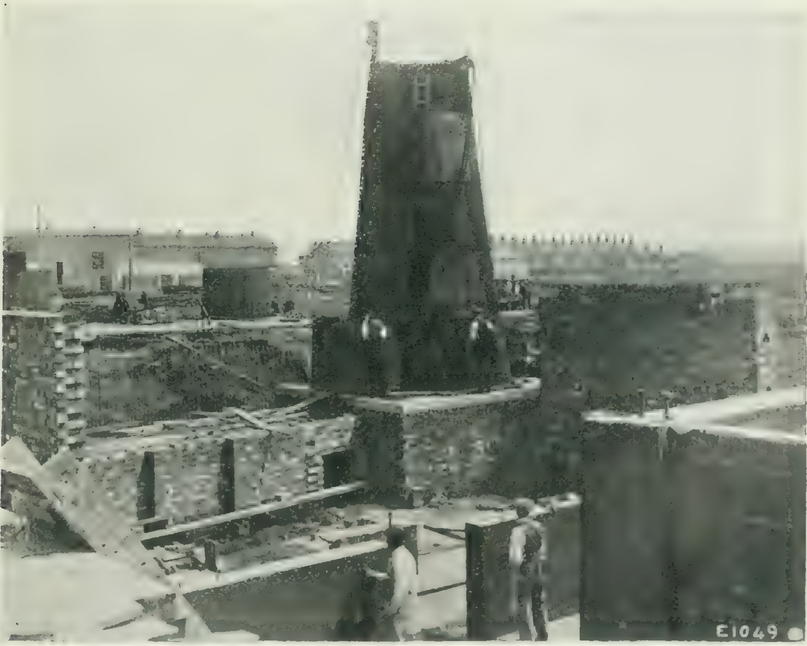

Fig. 8. Steel Chimney and Concrete Work to Boiler House
A Reinforced Concrete Factory, Birmingham.

is erected. In addition to these main bars there are three $\frac{7}{8}$ in. rib bars which are introduced at the points where brackets occur which carry the ends of the trusses. These trusses are spaced at 6 ft. 8 in. centres and they all bear on the beams and in no case come directly on to the columns. The brackets are provided on the pre-cast portion of the beam and they have a width of 12 in. and a projection of 7 in. The beam is also provided with $\frac{3}{8}$ in. diam. stirrups, at 4, 6 and 9 in. pitch throughout the length. A detail of a typical column and beam are illustrated in *Figs.* 3 and 5.

Roof Trusses.—The roof trusses were all pre-cast and a detail of one of these is shown in *Fig.* 6. The overall length is 19 ft. $3\frac{1}{2}$ in. and the principal rafters have a pitch of 30 and 60 degrees respectively.

As before mentioned, these trusses are spaced at 6 ft. 8 in. centres, and although this appears rather close, it is a distance which was fixed by the B.S.A. Company because it is a standard spacing adopted by them for the attachment of shafting, motors and gear generally, which is all carried overhead and standardised, so that any part is interchangeable, not only in one shop but over the whole works generally. This method, of course, provides considerable additional loading to be carried by the trusses, but it is an excellent method because all the motors, pulleys and shafting are very accessible, while the maximum clear floor space is obtained for machinery. As will be seen the truss is designed with a single strut to the long rafter and the whole of the reinforcement is hooked or turned at the ends to tie the adjacent members well together.

The tie beam is 10 in. by 7 in., the long rafter 9 in. by 7 in., the short rafter 6 in. by 7 in., and the strut and intermediate tie are 4 in. by 7 in. Each member is reinforced with four bars, with $\frac{3}{16}$ in. diam. binders, at 6 in. pitch throughout. Notches 4 in. deep are provided at the ends where the truss bears on the beam brackets and holes are provided, which allow the truss to be bolted to the beam with a small steel angle cleat as a precaution against any slight tendency to move out of the vertical plane during the placing of the roofing material. Projecting ties, $\frac{3}{16}$ in. diam. and spaced at 12 in. centres were arranged along the back of the long rafter and at the foot of the short rafter for fixing Hy-rib which was used in connection with the roof covering.

Roof Covering.—This covering consists of concrete 3 in. thick, which was placed on the Hy-rib without the use of any shuttering, and the undersurface was afterwards plastered to cover the reinforcement which was thus exposed. The top surface is finished with a patent roof covering which is dressed down into the gutters and over the glazing which occurs on the north slopes, small wooden fillets being cast on the concrete where required for fixing down the edges of the covering material.

Filling of Wall Panels.—The filling of the wall panels between the columns is executed in brickwork. In connection with the casting of the members it is interesting to note that the builders were enabled to continue work throughout the frosty weather by means of a simple method of heating any newly formed members. The members were cast in stacks by laying down a level platform on which was placed the shuttering, this consisting of a form of the required shape without top or bottom, the latter being formed by the platform. The reinforcement which had been previously assembled was then placed in the mould and the concrete deposited. When the latter was sufficiently hardened the form was slightly loosened and raised up to the top of the member and the placing of the steel and concrete repeated. The member already cast thus formed the bottom of the mould, and this was covered with a layer of oiled paper to prevent adhesion between the two units. This process of casting and raising was continued until the stack reached a height at which convenience ended, and the result was a series of units cast flat, one above the other, which was left to season as required. Several stacks were in progress of formation at the same time, and thus the work could proceed continuously by the workmen passing on from point to point in rotation.

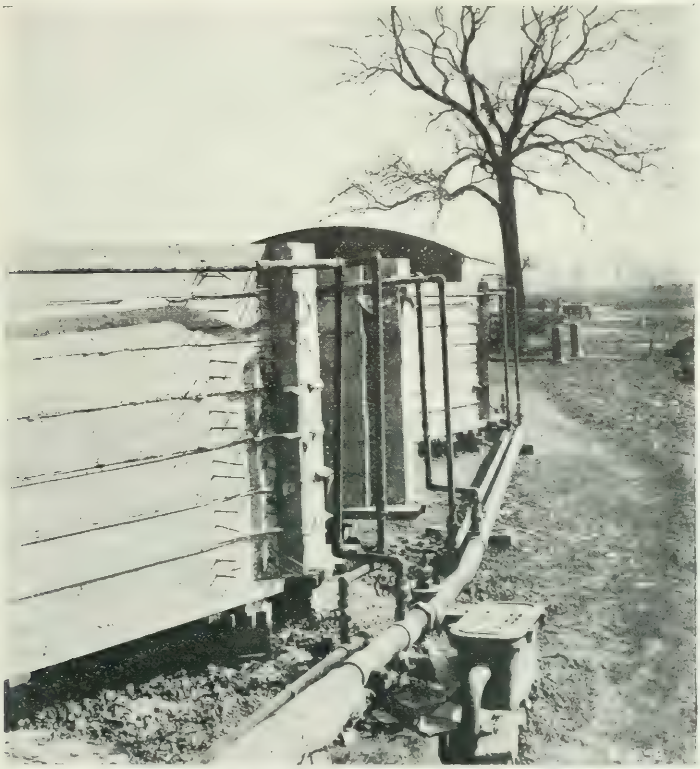

Fig. 9. Method of Heating during Casting.
A REINFORCED CONCRETE FACTORY, BIRMINGHAM.

Method of Heating during Cold Weather.—The heating during frosty weather was accomplished with a portable boiler, from which a steam main was led along the ground, this main having a tee-piece and valve at each stack. A loop pipe following roughly the same shape as the stack was provided at each of these points and the loop pipe was raised as the work proceeded, and the heat was therefore conducted to the newly placed concrete to keep the surrounding air well above freezing point. (See photograph, *Fig.* 9.) The cost of this heating was negligible, and valuable time was saved by the continuous procedure and the men were kept together during the whole of the period.

Other Interesting Features.—An uncommon feature of the work is that, owing to the need for keeping all the available men on the concreting and other heavy labour, girls were employed for the bending and preparation of the links and light reinforcement by means of specially designed tools, and this method proved very successful.

For lifting and moving the units when seasoned 2 portable cranes were used, these picking up the members in the ordinary way and travelling with them to the building, where they were placed directly into position and connected. The actual assembling of the parts was therefore a very speedy matter, and the concrete covering and other *in situ* work could follow on continuously. A portable electric crane was also installed on the site itself and this assisted in the lifting of the units, and, having a specially long jib, it was able to lift up concrete in skips over the assembled members and deposit same in the required position on the roof slopes without the use of any runways, hoists or barrows. All the concrete used was composed of 4 parts of $\frac{3}{4}$ in. granite chippings, 2 parts of sand and 1 part of Portland cement. The ground floor is formed with a layer of plain concrete covered with granolithic.

The reinforced concrete work was designed by the Trussed Concrete Steel Co., of Westminster, and executed by Messrs. Harvey Gibbs, of King's Heath, the general contractor for the building.

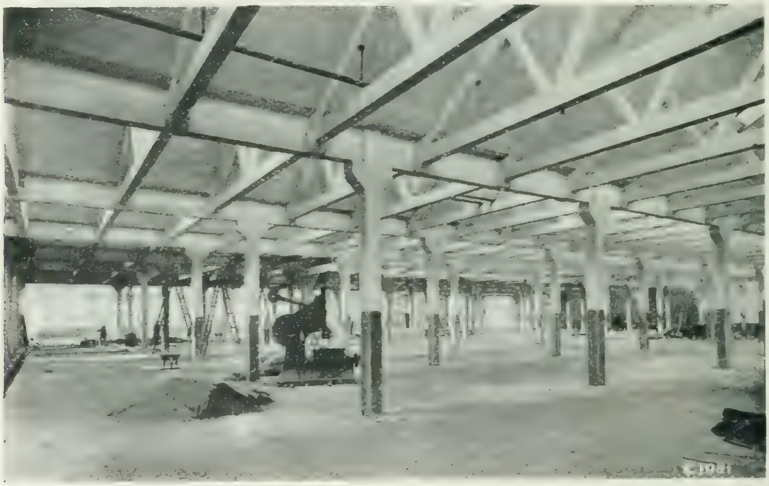

Fig. 10. Interior View.
A Reinforced Concrete Factory, Birmingham

THE HOUSING QUESTION.

At the Annual Meeting of the American Concrete Institute a number of Papers were read dealing with the housing question, a matter which is occupying considerable attention everywhere. In the present issue we reproduce (1) A Report of the Committee on Industrial Concrete Houses; (2) A Paper read by Mr. E. G. Perrot on "The Architectural Design of the Concrete House"; and (3) A Paper by Mr. Milton Dana Morrill on "The Interior Construction of the Industrial House."—ED.

REPORT OF THE COMMITTEE ON INDUSTRIAL CONCRETE HOUSES.

OWING to the late date at which the committee was appointed, the work done must be considered as simply of a preliminary nature. Some information has been gathered and some exchange of views has been made between the members of the committee in the report as now put forward and the papers already presented at the convention, some idea will be given of the scope of the subject and its importance to the country in general and to the American Concrete Institute in particular.

The concrete house is now an accomplished fact. It has come to stay. For many years experiments have been made with many types. Many of the earlier houses were quite unsuitable and showed defects, but the later examples are much improved, the earlier defects are being eliminated and the concrete house as built to-day is a thoroughly sanitary, weatherproof, permanent and fireproof home. It approaches more nearly the ideal home than any other type of construction.

DEFINITIONS.

The expression, "concrete house," is a rather indefinite term conveying different meanings to different minds. In order to make this report clear the committee have defined the concrete house as a house having external walls of monolithic concrete precast concrete or concrete blocks. A house which also has internal partitions and floors and roof of concrete we describe as "all-concrete house." A frame building covered with stucco or gunite is not considered to fall within the definition, "concrete house," and is defined as a "cement covered house."

CONDENSATION TO BE GUARDED AGAINST.

We have found that there exists in the minds of the layman an impression that concrete is damp and unhealthy. It is most unfortunate that concrete should have such a reputation even though we have found some earlier houses that give some justification for this criticism. It will be recognised by members of the Institute that while a concrete wall may be perfectly waterproof it is subject to condensation on a wet day unless the walls are furred and plastered so as to get an air space insulation; this condensation is sure to be apparent. In some houses this has proved to be a very objectionable feature; in other houses inspected by members of our committee the tenants complain that on the family wash day the walls were very wet and on other days they were comfortable. Climate has a good deal to do with this.

RELATIVE COSTS.

The investigation of the committee have not shown that a concrete house can be built more cheaply than a wooden frame house. The relative cost of course varies in different localities according to the availability of different types of material, but speaking generally we find that the cost of a concrete house should run from 10 to 15 per cent. more than the cost of a well constructed frame house.

The advocates of the concrete house must rely upon the superior merits of concrete as a material and not upon its low first costs.

THREE TYPES OF CONSTRUCTION.

Three principal types of concrete house construction are the concrete block, the precast house and the monolithic house. We have not pushed our studies into the stucco house or cement-gun covered house, which seem to be outside of the scope of the committee. The general conclusions of the committee as to the merits of the various methods are that for small jobs the concrete block house stuccoed on the outside is the best solution, but for large developments in which more than 50 or 60 houses are required the monolithic or precast types show an economy in cost and speed that should place them in the foreground.

DIFFICULTIES TO BE OVERCOME.

In any type of concrete house construction difficulties are sure to be met with. Some of these are discouraging to the contractor entering this field and are likely to hinder its expansion unless faced and overcome. The committee have thought it well to discuss them frankly in order to guard the novice against disappointment and failure, realising as we do that these difficulties are incidental only and not insuperable. The successful work done is sufficient answer to any objection raised that concrete house construction is too difficult or impossible.

PRECAST CONSTRUCTION.

The precast house composed, as it is, of shop-made units of considerable size and weight needs a large outlay on equipment for hoisting erection and transportation of the units. This limits the use of this method to groups of houses which are large enough to amortise this outlay in a reasonable time. Great care also is needed in setting to prevent breakage, as a broken unit not only involves loss of spoiled material but considerable delay while fresh units are made. In order for a precast system to show economy the design of the houses must be alike in plan and uniform in design.

MONOLITHIC CONSTRUCTION.

The committee are agreed that wood forms are out of the question for monolithic house construction. Although the first cost is low the life is short, the upkeep high, and the results obtained are generally unsatisfactory. In any kind of concrete construction the concrete wall is more difficult to form than the floor, the foundations or other parts of the building, and it is therefore necessary to discard the wood form and search for something better if monolithic concrete houses are to be built successfully.

There are about a dozen metal wall forms for house construction on the market. One of these is made of structural steel channels, the rest of sheet metal. With certain forms a complete story can be poured at one time, but the greater number are designed to allow the pouring of one course (usually 2 ft.) at a time.

The structural steel form has the demerit of being exceedingly heavy, but on the other hand is easily set up true to line and giving a very good wall surface. The sheet metal form is not so easily kept true and is easily distorted and damaged, but with proper care can be used to produce excellent results.

EXTENT OF APPLICATION OF CONCRETE.

The committee has not come to any conclusion as to how much of the house should be built of concrete. Accordingly the members have presented their divergent views in their papers rather than attempt to come to any agreement so quickly. It is certain that the concrete wall offers great advantages due to its fireproof, weatherproof and permanent qualities. It should be furred inside. It should cost about the same as a brick wall or slightly less. A concrete floor should cost about 18 c. per sq. ft. more than a wood floor, concrete with wood top surface about 30 c. per sq. ft. more.

A granolithic floor is advocated by some on account of the ease of cleaning, but for poor families who cannot afford many rugs it is unsuitable and it is unhealthy for small children to play on a cement floor.

When concrete construction is used for constructing outside features like porch columns and roofs and mouldings, cornices and ornaments the cost of the house is increased very quickly.

EXTERNAL SURFACES.

Concrete being a new material, the tendency is generally to cover it up to make it look like something else, and therefore most of the concrete houses built up to the present time have been covered with stucco. With a steel form that gives a good even line concrete can be finished with a rubbed, or wire brushed or tooled surface that will be quite satisfactory in texture and in colour. And very artistic effects can be gained with the use of coloured aggregates. To finish with a wood float does not give a good result. The concrete house is superior to brick or any other type of house on account of its permanency, fireproof and weatherproof qualities and pleasing appearance. No repointing is necessary, no efflorescence disfigures its surfaces. The all-concrete house combines with these advantages the absolute rigidity which is lacking in a wood floored house, sticking of doors, settlement cracks in walls and in plastering are avoided, and there is no harbourage for vermin.

RESTRICTION LAWS.

Building ordinances framed to control brick tile and stone construction before the extensive use of concrete in wall construction are in most cases unduly burdensome and restrictive when applied to concrete. Six-inch walls are the maximum needed in monolithic construction and 2 in. is common in precast construction where other structural members carry the load. Most codes call for 8 in. and some as much as 12 in. thickness. Similar difficulties are found with floors A reform of our building laws is urgently needed in many of our big cities and the committee has in mind the preparation of a building code for concrete small house construction which will serve as a model for cities and suggest that after receiving the endorsement of the Institute it be circulated and urged upon municipal authorities.

There is a widespread interest in the concrete house to-day. There is not, however, much active demand for them, owing to the dearth of contractors experienced in concrete work who are entering this new field to create a supply. The majority of the small houses built to-day are built for quick sale by the vendor and not for investment. House-building standards have been low. Competition in prices has been keen, but quality has been a secondary consideration. The demand at the present time seems to be for a better type of construction—concrete meets this demand.

VALUE OF PERMANENT CONSTRUCTION.

The housing programme of the Government entrusted to the Shipping Board and the Department of Labour will set the standard of housing for many years to come. It is of the utmost importance that these standards should be higher than the low standards that now prevail and especially that the work done be of such permanent character that it may prove to be an adequate security for the funds expended and for long term mortgage bonds at low rates of interest.

We believe that the members of the Institute should use their influence to ensure that in the carrying out of this programme and in the other industrial housing work carried out by public funds or private enterprise the concrete house should occupy its rightful place.

Good and sufficient housing is one of the most pressing needs of the nation at this time. Without it we are seriously handicapped in the winning of the war. The provision of good housing is not only an immediate need but a permanent national gain and every member who lends his influence and aid to the securing of this end is rendering a real service to the nation.

ARCHITECTURAL DESIGN OF THE CONCRETE HOUSE.

By E. G. PERROT.*

WITH the growing importance of the necessity for permanent construction of good homes for the wage-earner is the all-important one of materials for construction coupled with successful architectural design.

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* Ballinger & Perrot, Architects, Philadelphia, Pa.

When viewing the successful creations of the small house for the wage-earner which found its early expression in modern industrial villages planned on Garden City lines, financed and built by industrial establishments, in England, notably at Port Sunlight, Bournville and Letchworth, we are surprised to find the high character of the architectural treatment of these houses. Their cosiness and real homelike effect contrast very strongly with our company houses in the United States, which will ever remain as one of the blots on the architectural horizon, since the opportunity to combine the utilitarian with the æsthetic has been, it would appear, almost studiously avoided, when it would have been possible, with a little care and study, to have approached nearer to that which we are now striving to attain, namely, cheap artistic homes for the wage-earner

CONCRETE AS A BUILDING MATERIAL.

Concrete as a building material, having been used mostly in its early application to building construction and engineering work, has been left to the chaotic caprice of the uninitiated in the realms of fine arts to be developed more in a structural manner than has been good for the effect on the public at large. This has been so much so that the architectural profession has concerned itself less with the ornamental treatment of concrete than with its structural importance.

Good architectural design is based on unity, grace and proportion. It is by the adaptation of the first and last of these fundamental qualities that concrete can simulate a design which might be suitable for any other material of a plastic nature, such as stucco on brick or hollow-tile, or of even simple types of brick buildings.

Many of our present types of domestic architecture lend themselves, with very little modification, to reinforced concrete.

In the treatment of the exterior design, a style that depends upon plain wall surfaces with well-proportioned and properly related openings, with the avoidance of projecting mouldings, useless and meaningless ornamentations, etc., is the one which can easily be executed in concrete. It is very essential to studiously avoid moulded and under-cut bands and projections. Flat bands forming string courses and panels may be judiciously used when the style of architecture demands such treatment.

Whether the roofs are to be flat or high pitched depends generally upon the climatic conditions of the locality in which the houses are to be built. We all know that the pitched roof in colour lends very much to the attractiveness of a house. A low-walled and high-roofed house more easily produces the effect of the house being a part of the ground, or, in other words, as growing out of the ground instead of simply standing upon it. This feature of making the architecture indigenous to the soil is the one which, more than any other, is so characteristic of the many beautiful industrial villages seen in England.

It has been found to be more economical in the cost of construction to build houses in groups or rows, limiting them to rows not exceeding eight or ten, than to build single or twin houses. A great many varied effects can be obtained in the group system by the use of projecting pavilions, gables, etc.

EXTERIOR SURFACE.

One feature that should be given consideration in the exterior of the concrete house is its colour. The unattractive mouse colour of concrete cannot be made to satisfy the colour instinct in man. It is for this reason that the poured concrete house, unless treated with a special aggregate or other means to enliven the colour, is bound to be a failure.

Where an extensive housing programme is contemplated, one method of using concrete which permits of beautiful colour effects as well as artistic design is by the cement-gun. It appears that much can be gained by a study of how the gun can be brought into more universal use in house building. In connection with stucco work along the Pacific Coast it has been very successfully employed, while in the east its use in connection with engineering structures has of late been brought into great prominence. There is still a big field for its application in connection with houses, which the writer feels will solve many of the complications of the problem.

CONCRETE BLOCKS.

The use of concrete blocks for houses is restricted to certain sizes and shapes of blocks, and, although made to imitate natural material, stone, their use is unartistic from the purely architectural point of view, and for that reason have not been adopted by architects generally. Walls built of rough concrete blocks, however, can be stuccoed with hand-placed mortar. Tile inserts, properly placed, make a very effective design, especially if the coloured tiles are judiciously used on piers, panels, and in string courses.

MONOLITHIC WALLS.

Monolithic concrete walls can best be coloured by using coloured aggregates, surface scrubbed, thereby removing the outer film and leaving the coloured aggregates exposed to view. If it is not possible to do this, the wall can be tool-dressed with a pneumatic tool after the concrete has hardened. From the writer's experience, a light pebble forming the fine and course aggregate in the concrete, with a scrubbed or tooled finish, makes an excellent exterior for poured monolithic walls. However, as this material is not available in all localities, it is necessary to adopt a treatment of the exterior that can be obtained by materials at hand, using tile inserts as previously mentioned above.

CONCLUSION.

Therefore, if we are to look for a solution of the architectural expression of the concrete house, we must get away from what has hitherto been satisfactory from a purely engineering standpoint. We must remember that a house, in order to be successful, must simulate the home spirit and, if I may use the term, have a little of that quaintness which is not found in a great many " stiff " creations parading under the name of houses. Many are merely wooden or concrete boxes.

I realise that what I have said may not be very encouraging to those whose efforts have been put forth to advance concrete house construction, but if we are to place this construction in the class of other materials which have long since been recognised and used by all peoples as meeting æsthetic demands we will have to adopt the same fundamental principles which form the basis of all true art.

The dawn of a bright era appears to the writer to be approaching, and he trusts these few remarks will tend to point in the direction where a happy solution of this complex problem will soon be found.

INTERIOR CONSTRUCTION OF THE INDUSTRIAL HOUSE.

By MILTON DANA MORRILL.

In the consideration of the best interior construction for industrial houses, let us take for example these built and owned by a manufacturing or holding company to be rented by the families of the employees.

These houses must be expected to stand hard service. They will be occupied by one family after another, and moving furniture is hard on the house interior. There will be some large families with several children and many with three or four lodgers. Experience shows that some of these families will keep their houses spotlessly clean, while others will be indifferent as to dirt, insects, fire risks and care of the house generally.

The interior of the industrial house should fulfil the following requirements :—

(1) The rooms should be light and cheerful, free from dampness, warm in winter and cool in summer.

(2) Such a house interior should be free from dust-catching woodwork.

The surfaces and finish should be as waterproof as possible so that the house may be washed out, scrubbed and thoroughly cleaned between rentals.

(3) In the construction cracks, crevices and concealed spaces should be avoided, as they are likely to harbour and offer a breeding place for vermin and insects.

(4) The construction should be fire resisting or, better, fireproof.

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(5) The construction should be reasonable in first cost, permanent and capable of resisting hard usage with a minimum expense for upkeep and repair.

TYPES OF INTERIOR CONSTRUCTION.

Let us consider three of the possible types of interior construction for industrial houses, (1) A house with masonry walls, the usual wood floor beams, board floors, lath and plaster ceilings, wood stud partitions lathed and plastered ; a non-fireproof construction. (2) A house with masonry walls, reinforced concrete floor slab covered with wood sleepers and board floor, bearing partitions of concrete or tile ; fireproof. (3) A house with a concrete floor and cement finish partitions concrete or tile ; fireproof.

The first type of construction is the least expensive in first cost and has the advantage of being the kind to which we are all accustomed. An interior of this kind with wooden floors, door casings, base and window trim seems the most comfortable and home-like. We would like to stop here and forget that most disastrous fires gain their headway in the open spaces and dry timbers of these wooden floors. We would also like to forget that these concealed spaces in the partitions and floors form ideal breeding places for insects and vermin. A house interior of this construction can never be completely cleaned. One untidy or careless tenant can ruin such a house. What is worse, through the neglect of proper precautions in case of tuberculosis, for instance, he might imperil the health of future tenants.

The second type of construction is an improvement over the first. The fire hazard is eliminated by the concrete floor slab. The wooden floors laid over the concrete give the house a familiar and home-like aspect. For the industrial house this type of construction has the disadvantage of being the most expensive.

The third type is a house with a concrete interior. Such a house can be made sanitary to a degree. There are no hidden spaces in the construction, therefore insects must live in the open if they live at all. On a trip of inspection to Nanticoke, Pa., the writer saw one of these concrete houses being scrubbed out from top to bottom in preparation for a new tenant. After occupancy for many years these houses will be in good condition and soap and water will make them fresh and clean again the same as it does to-day.

The house with a concrete interior has the further advantage of permanency and capacity to withstand hard usage. The expense of upkeep and repair therefore is reduced to a minimum and depreciation becomes almost nil except on the doors, windows, plumbing fixtures, etc. Fire insurance becomes unnecessary, as there is little or nothing about such houses to burn.

On the other hand, there are objections to the house with the usual concrete interior. During the past five years the writer has had the opportunity to inspect in all 83 houses with concrete interiors. It may be of interest to note here this list :—

12 dwellings built under the Small-Harms patent in Paris, France.
8 houses built under the Roughsledge system for the Canadian Cement Co., near Montreal, Canada.
20 dwellings at Gary, Ind., for American Steel and Wire Co.
40 dwellings at Nanticoke, Pa., for the D. L. and W. R. R. Co.
1 house at Brentwood, Md.
1 house at Virginia Highlands, Va.
1 house at Union Hill, N.J., built under Mr. Simpson's plan.

The interior appearance of the majority of these dwellings is crude and unfinished, while from a structural standpoint the superiority is very marked. The question therefore arises, how may the interior appearance of the concrete house be so improved as to make it more attractive and comfortable ?

SUGGESTIONS FOR IMPROVING THE INTERIOR OF A CONCRETE HOUSE.

Let us look into the possible changes that might be made in the finishing of the interior of a concrete house and see if some of the objections and faults cannot be overcome. We must remember that the art is new and that most of the useful things about us were not in their first stages the beautiful articles that they are to-day. One error that some of us have heretofore made is in trying to produce such houses at too low a cost. In the interior treatment just as in the exterior construction we can afford to go to more expense than is usual in the ordinary house, for the building is for all time. It is almost an axiom that the permanent building is the low-cost building in the long run, and a concrete house with a concrete interior should with a minimum of repairs give service for a long period of years.

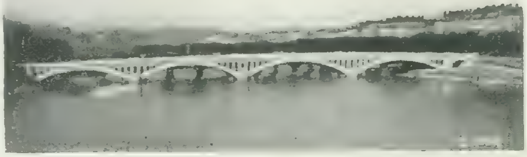
Floors.—The cement floors have perhaps been considered as the greatest drawback in the fireproof house. There is no denying the fact that the cement floor without rugs or matting is a hard surface upon which to live ; however, most of our modern hotels and office buildings as well as the modern tenements are now using cement floors, and no serious complaint is made after the tenant has become accustomed to them.

If the cement floor could be given a more attractive finish, prejudice against it might be overcome to some extent. Such floors might be finished with a terrazzo surface and at a cost that is not excessive where machine grinding can be employed, or the floor may be finished with a surface of white portland cement and marble dust. A floor of this sort can be waxed and polished much the same as a wooden floor. In some of Mr. Simpson's plans he proposes using a cove base of hard wood which is let in flush with the cement. This would serve as a tacking strip for carpets if such are desired.

Walls.—The treatment of the interior walls of the concrete house does not differ materially from houses of other construction. For industrial houses it is generally conceded that painting is the most sanitary and satisfactory finish for the walls. The usual wood trim or casing around the windows and doors may be used, or if desired this can be altogether omitted, the plaster returned with a slightly rounded corner, making a simple and sanitary finish.

Fixtures.—In the industrial house, built-in fixtures and cupboards should be bracketed from the walls where possible, as this leaves the floor space clear for ease in sweeping and cleaning. Curved corners where walls meet and at the base and ceiling help in cleaning also. In time the wash-tub, bath-tub and kitchen sink for the industrial house will without doubt be moulded in concrete, but at the present stage of the art enamelled iron is a far better and less expensive material to use for these fixtures.

Stairs.—In the house with a concrete interior the stairs may be of the same material. The risers and treads can be precast and set in place. The stair railing can be made likewise. Where cost permits, decorative tile or precast panels may be set in the house walls ; stencilling makes also an attractive way to apply simple decoration.



THE WILSON BRIDGE AT LYONS.

*The following summary-translation of a detailed description of the bridge has been made by **A. B. Searle** from the French journal, "Le Génie Civil." For our illustrations we are indebted to **M. Chalumeau**, the designer of the bridge.—ED.*

THE new bridge across the Rhone at Lyons, opened on the 14th of July last, and named after the illustrious President of the United States, is built on the Séjourné system, in which the main arches are surmounted by a series of pillars arranged in two rows, and these in turn support a large slab of reinforced concrete which carries the roadway on top of the bridge. This arrangement effects a great saving in cost and facilitates construction without in any way detracting from the appearance of the structure.

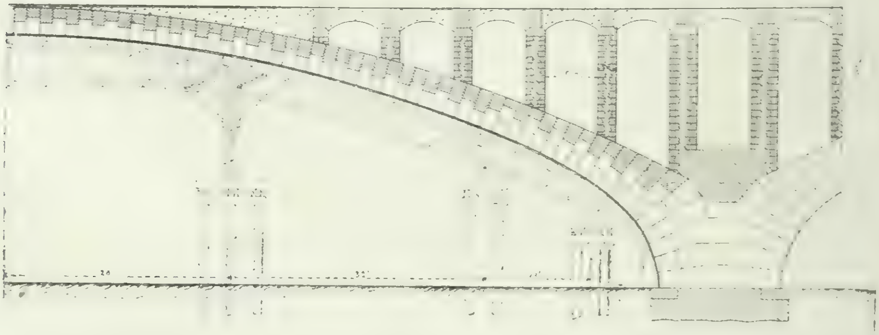


Fig. 1. **Half of Main Arch showing Superstructure.**
The Wilson Bridge at Lyons.

The Wilson Bridge has four main elliptical arches with a span of 140, 150, 163 and 150 ft. respectively, and two end arches with spans of 25 ft. and 37 ft. The length of the bridge is 760 ft., and the width between the parapets is 67 ft., including a roadway 37 ft. wide and two footpaths each 15 ft. wide. The pillars are each 17 ft. wide, and the two rows of pillars are 36 ft. apart.

The large concrete slab was reinforced on the Hennibique system, its construction requiring 12¾ months. This slab measures 740 ft. by 54 ft. ;

its cubic content is 45,000 cu. ft., and 270 tons of steel and 425 tons of Portland cement have been used in its construction.

The roadway and footpaths are carried by trapezoidal beams nearly 6 ft. in height at the centre and 3 ft. at the ends, resting directly on the arches. These beams are formed of members 13 in. by 16 in. above and 14 in. by 10 in. below, with 10 in. by 14 in. ties ; in the space between the ties are 4 in. webs ; the dead weight of the structure being thus reduced to a minimum. The two extremities of the beams rest on the pillars by means of a supporting piece 28 in. by 20 in. connected with another block 20 in. wide.

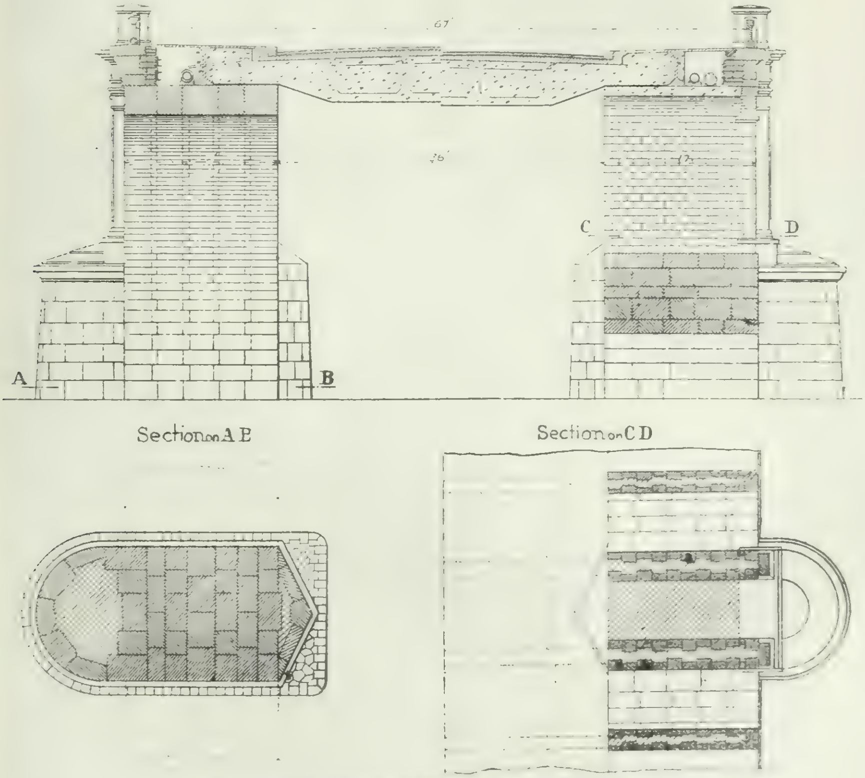


Fig. 2. Transverse Section as Plan of Superstructure.
THE WILSON BRIDGE, LYONS.

The roadway is paved with creosoted blocks ; the two footpaths are asphalted. Under each footpath is a rectangular channel 4 ft. 8 in. by 3 ft. 10 in. to accommodate gaspipes, electric cables, telephone wires, etc. ; each of these can readily be inspected at any point.

The use of wrought stone for the four main arches gives a monumental and massive appearance to the whole bridge, whilst the simultaneous use

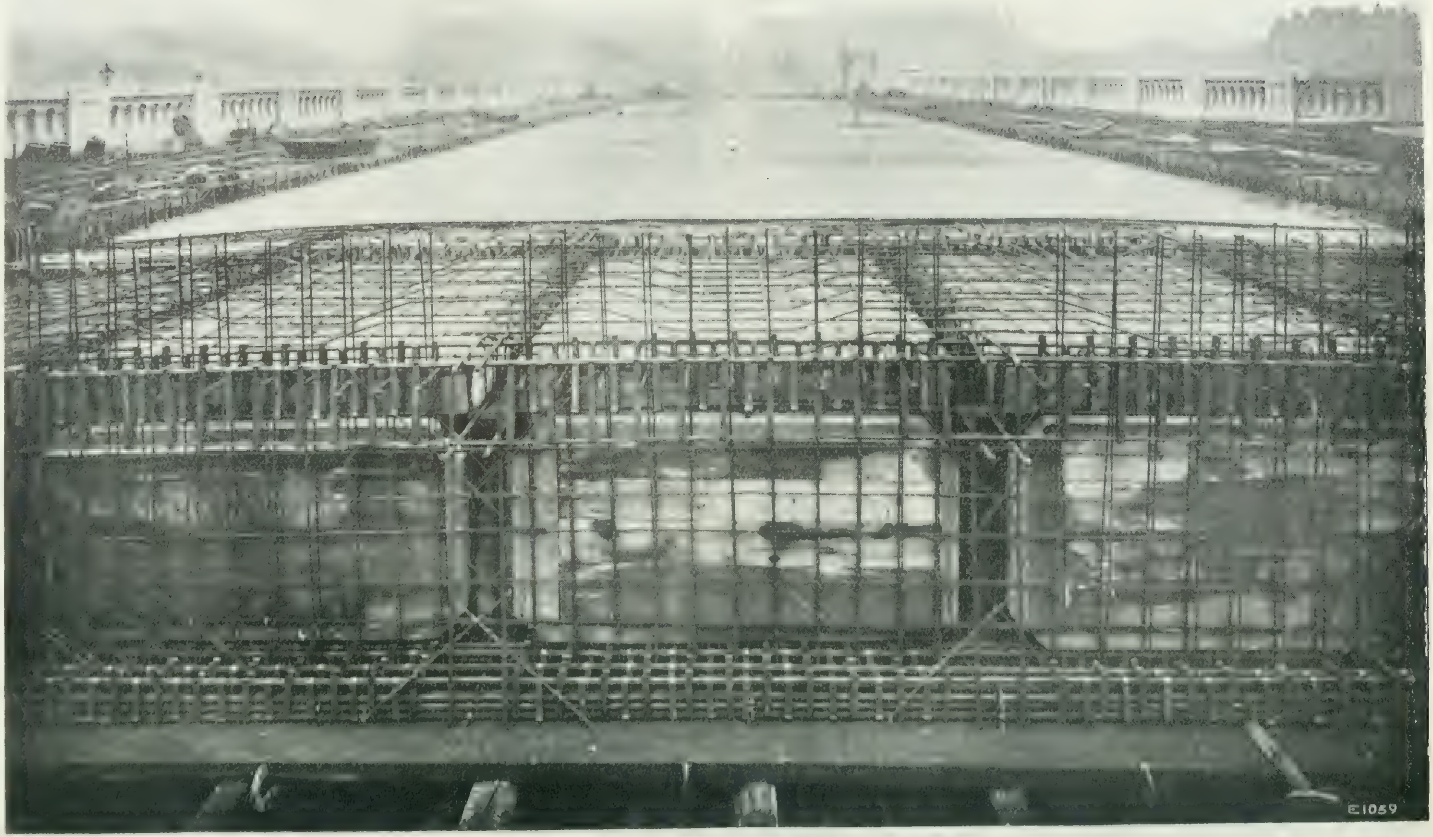
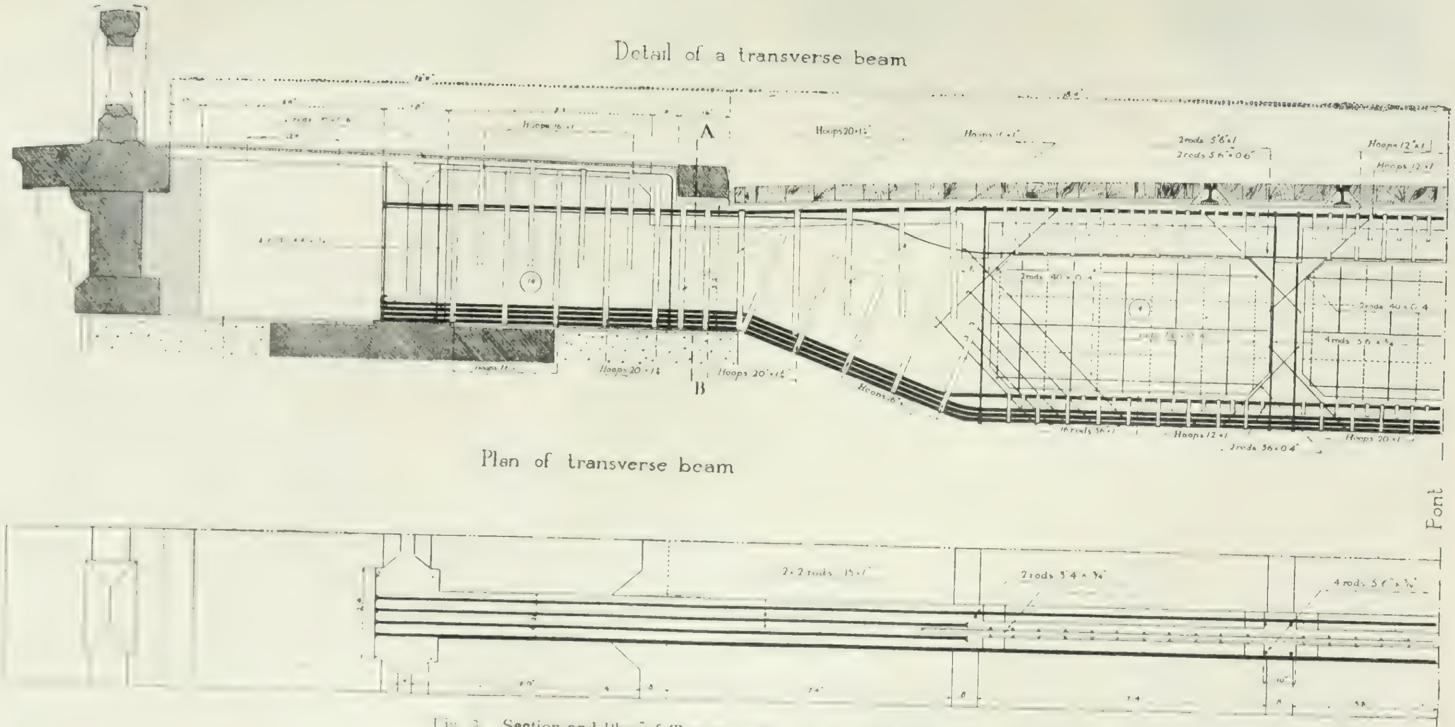


Fig. 4. **Transverse View of centre of concrete slab showing Reinforcement.**
The Wilson Bridge, Lyons.

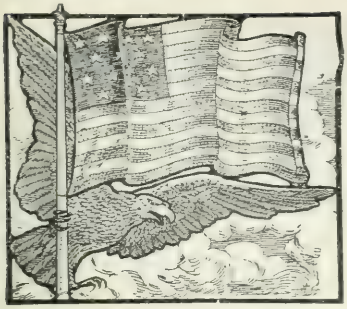

Detail of a transverse beam

Plan of transverse beam

Fig. 3. Section and Plan of Transverse Beam, showing Reinforcement.
The Wilson Bridge, Lyons.

of reinforced concrete for the upper portion enables this part to be built lightly whilst maintaining ample strength. The width of the supports of the main arches is only one-tenth of the span of the latter and is in marked contrast to many other stone bridges in which the width of the pillars is more than a quarter of the span of the arches. This arrangement not only adds grace to the appearance of the structure, but reduces the amount of masonry exposed to the water and greatly increases the waterway—an advantage which can be readily appreciated in the case of a river subject to such violent fluctuations as those of the Rhone.

The bridge was designed and executed by M. Chalumeau, engineer-in-chief to the Municipality of Lyons.



CONCRETE IN SEA WATER.

(Concluded.)

By R. J. WIG and L. R. FERGUSON.

V.

The present article concludes the series we have been publishing regarding Concrete in Sea Water, and, as will be observed, the authors, in the present article, lay the greatest emphasis on the necessity of good workmanship if concrete is to withstand the effects of sea water Other points touched on are the need of correct proportioning, the judicious use of water-tight forms, and efficient supervision.—ED.

THE character of the workmanship has an important bearing on the ability of concrete to resist the action of sea water. Only contractors of experience, employing competent men, should be entrusted with important work in sea water, where the difficulties usually encountered cannot be overcome by any but the best of organisations thoroughly equipped with the necessary tools and machinery. Letting of work to the lowest bidder usually proves a costly procedure.

EXTREME CARE NECESSARY IN BUILDING.

No matter how carefully the structure is designed, careless methods used in construction will cause trouble. Unfortunately, imperfections cannot be detected at once, and frequently patches and a wash of cement grout over the surface hide for a little while defects which ultimately result in failure.

But the defects due to workmanship cannot always be attributed to carelessness. Engineers have employed methods which they believed would produce superior results but which as a matter of fact frequently caused failure. The necessity for extra care in building concrete structures subjected to sea water action has not been appreciated. As a rule engineers have followed common practice and permitted about the same quality of work in their sea water structures as they secure for those on land.

This must be changed if the trouble now so prevalent with concrete in sea water is to be overcome. It is not only necessary to erect better concrete structures in sea water than on land, but this must be done in the face of increased difficulties. Engineers must provide more rigid and intelligent inspectors, in whom are placed implicit confidence, and they must insist upon the contractor following instructions. And when controversies arise the engineer must support the inspector but these requirements must be made plain in the specifications, so that misunderstandings will be avoided and all will work in harmony, for only by so doing will the best results be secured.

MINOR DEFECTS CAUSE TROUBLE.

The necessity for extreme caution in every detail of the erection of a concrete structure in sea water cannot be too strongly emphasised. Even what would be considered very minor defects in a land structure must be avoided in sea water work, for these defects are points of weakness which are readily attacked, and disintegration once started spreads to adjoining sections, causing failure.

The experience gained in one very large project which included several thousand pier structures is interesting in this connection, as it shows how greatly the quality of concrete in sea water can be improved by the exercise of extreme care. The piers were built in forms sealed at the bottom with concrete deposited through a tremie. This seal acted as the footing for the piers, and after it had set the water was pumped out of the forms, and the balance of the pier was constructed in the dry.

In the first work, embracing more than two hundred structures, which was done in accordance with usual methods, more than 50 % of the footings were found to be seriously defective. When this condition was discovered, the necessity of using far more care was seen, and a marked improvement in the character of the workmanship was insisted upon for the next several hundred structures. The result was that only about 1 % of these piers had any defects. The engineers were not yet satisfied and insisted upon even more attention to details, and as result the last several hundred piers have shown practically no defects whatever.

According to the reports of inspection, the defects were caused by improper use of the tremie, by leakage of the forms at the bottom edge, by lack of thoroughness in the removal of sand which had washed into the forms before the concrete was deposited, by lack of care in thoroughly cleaning the surface of the old concrete when re-sealing was necessary, and in some cases by the breaking of corners in the removing of forms.

The defects in the piers have been repaired, the same care being used as in the recent work, and now they are all in good condition.

GENERAL PRINCIPLES TO BE FOLLOWED.

The methods to be followed in sea water concrete work depend in certain details upon the location of the structure, as this governs the rigour of the climatic and sea action, and also upon the particular design employed, this too being governed considerably by the conditions to which the structure will be subjected. Certain general principles can be followed, however.

The forms should always be made tight, so that leakage of the concrete will be prevented. For work below the low-water line this is just as true as for that above. The best under-water work is secured by erecting a cofferdam and building in the dry, but this is expensive and at times impossible. When the bottom of the work is at a depth below water which prevents its being seen from the surface, the services of a diver are essential, for the forms must be carefully examined to insure their tightness. Leakage is most likely to occur around the bottom edge of the forms where they rest on the ground. In such cases the washing of the tide carries away the mortar from the concrete, leaving honeycombed sections which are readily cut away as soon as the forms are removed. This undermines the supporting parts of the structure, and settlement and cracking result. A very simple and effective method of preventing the trouble is to plug the crevices around the bottom edge of the forms with bags filled with sand, or, better still, bags of concrete.

A popular form of construction where limnoria and teredo are not found is that of wood piles cut off at or near the low-water line and supporting a wood platform on which rests a gravity-section concrete wall. Where this type of structure has been used it is not unusual to find the lower outside edge disintegrated. This is due largely to the fact that the joint between the face form and the platform on which the wall rested was not made tight. The bottom layer of concrete is deposited when the tide drops to the lowest point. This, however, is frequently but little below the platform, and so the water rises to that elevation shortly after the concrete has been placed. If there is any leakage along the bottom edge of the front form the fresh, soft concrete is very likely to have the mortar washed from it along this section. This results in a porous mass which is readily attacked.

The bottom joint, however, is not the only one which should be tight. They should all be tight. It is advisable to use lumber surfaced on the edges and inside face; and in some instances where the wash of water is severe, tongued and grooved material should be used. Smoothness of the exposed face of the concrete assists materially in resisting sea water attack, and this cannot be secured unless forms are carefully made of surfaced lumber.

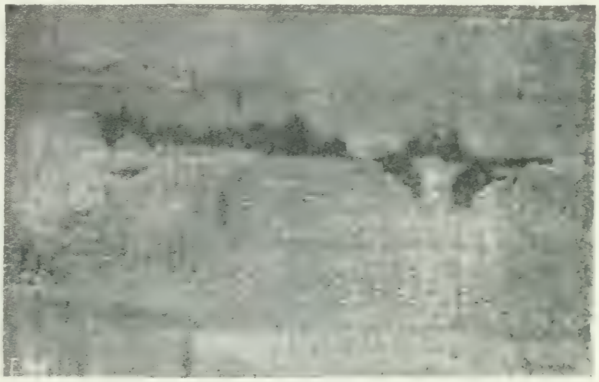


FIG. 23. FISH OIL ON THE FORMS CAUSED SOFTENING OF CONCRETE SURFACE.

If the forms are oiled, and this is preferable, a mineral oil should be used. Practically any kind of mineral oil is suitable, and cylinder oil has been much employed. Two or three applications of kerosene serve better than cylinder oil in preventing the sticking of concrete, and this has the added advantage of not staining.

The forms for the concrete wall of a Canadian wharf were coated with fish oil. This caused a soft, pitted and chalky surface which is porous and easily abraded. Very soon after the removal of the forms places were observed where the fish oil had disintegrated the concrete. See *Fig.* 23.

CORRECT PROPORTIONS IMPORTANT.

After the materials are selected the concrete must be proportioned to secure the maximum density. Density and strength are closely related and generally the concrete with the greatest density will possess the most strength—that is, when made from given ingredients.

Proportioning by means of void measurement is not satisfactory, nor is a mixture based upon granulometric measurement. The best method of arriving at the proper proportions is actually to mix the cement, sand, and stone together with the amount of water to be used and by trial determine which mixture produces the minimum resulting volume from given amounts of the ingredients, measured separately. This subject is discussed at length in Technologic Paper 58 of the Bureau of Standards, and in many other technical articles.

The stronger and tougher the concrete the less likely it is to be chipped and abraded, with the consequent exposure of the interior of the mass to chemical attack. The denser and more compact the concrete the less will be the absorption of moisture, and with the diminishing of the absorption the possibility of initial disintegration from frost action will be materially lessened. The present almost universal method of arbitrarily specifying the proportions of the concrete is not scientific and in most cases does not produce the best grade of concrete from given ingredients. Far more care than has previously been used must be exercised in determining the best proportions, and then there must be insistence that the proportions determined upon are rigidly adhered to by the contractor.

Generally it is advisable to use richer mixtures than would be used for similar structures on land. The sand or stone will vary somewhat, even though it comes from the same source, and so it may be necessary to vary slightly the proportions as the work proceeds. In order to secure continuously the best grade of concrete the engineer should make tests at frequent intervals, not only of the ingredients of the concrete, but also of the concrete itself as mixed by the contractor.

A city on the Pacific coast which has been spending millions of dollars in improving its harbour facilities and building large concrete docks maintains a well equipped laboratory exclusively for this work. Here tests are made daily to determine the quality of concrete the contractors are producing and also to keep a constant check upon the aggregates being supplied. In this laboratory the proportions for the concrete are determined, and as it becomes necessary these are varied from time to time. The inspectors on the work are given power to insist that these directions be explicitly followed.

The amount of water used in mixing is of even greater importance, perhaps, than the proportioning of the concrete. This is particularly true for sea water work. If too little water is used the concrete is porous and the surface lacks smoothness and density ; if too much is used the concrete is also porous and the surface chalky and weak. The proper consistency is one just dry enough to permit of *light tamping*, but not so dry as to require any effort to bring water to the surface. This is hardly wet enough to use for reinforced work, and for this class of construction a little wetter consistency must be used ; but a very slight addition in the amount of water used in the mixing will produce a marked effect. The influence upon the strength and porosity of the concrete exerted by varying the amounts of water used in mixing has been emphatically demonstrated in recent publications. The use of excess water may decrease the strength 50% and greatly increase the porosity and friability.

The effect of the consistency employed on the ability of the concrete to resist sea water action was forcibly emphasised in many instances during the examination made by the writers.

There is a pier on the New England coast which illustrates this excellently. This pier was built under two contracts, the outboard section being completed first, after which the inboard section was begun by another contractor. The designs for both sections were exactly the same and the ingredients used in the concrete were identical. There is practically no difference in the exposure condition. The outboard section was constructed under the direction of an

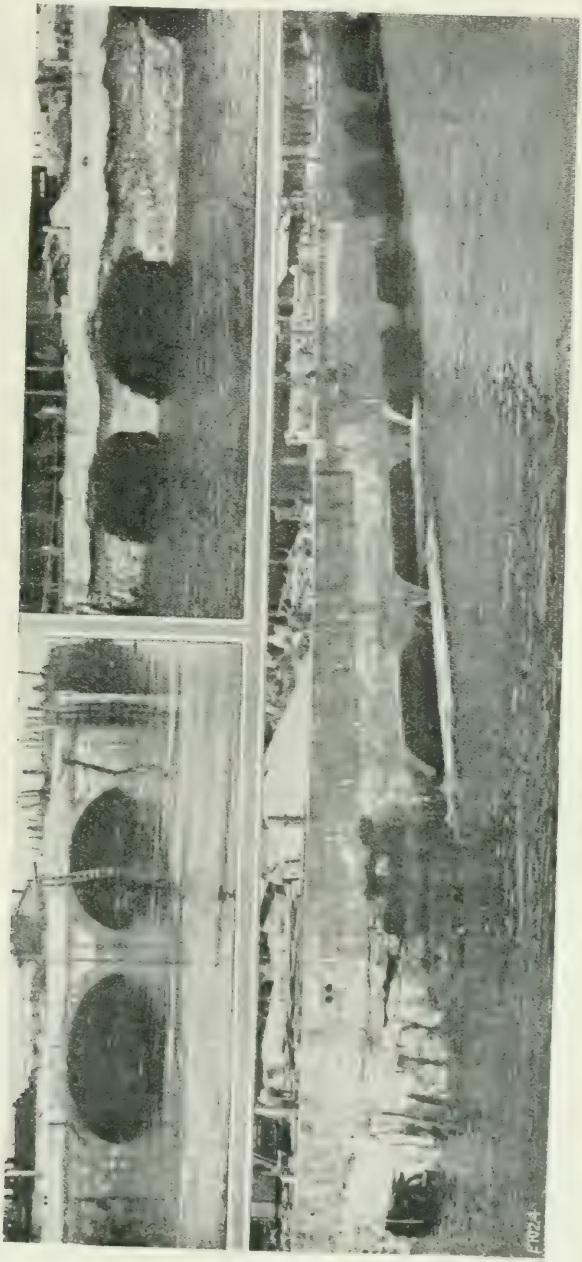


FIG. 24. HOW CONSISTENCY AFFECTED THE WEAR OF ONE CONCRETE PIER.

Upper left hand view is outboard end of pier made with dry concrete just after completion. Upper right hand view shows same section eight years later. The lower view shows excellent condition of medium consistency concrete at right in comparison with wet consistency at left.

engineer who believed thoroughly in dry concrete, as did most engineers at that time. Even before this section was completed there were evidences of disintegration in some parts of the work as shown in one view in *Fig.* 24. The condition of the same wall eight years later is shown in another.

About the time the inboard section was started another engineer was put in charge of the work. He decided to allow a little more water to be used, though not so much that tamping could be dispensed with. The inspectors stated, however, that very little tamping was sufficient to settle the concrete into the forms. The conditions of exposure to which this pier is subjected are severe, but in spite of the fact that there is no adequate fender system, the inboard section is in excellent condition after fifteen years of use, while the outboard end continued to disintegrate to such an extent that about five years ago extensive repairs became necessary to prevent collapse of parts of the structure. When these repairs were made the wets were in power and a sloppy consistency was considered the proper thing for all concrete work. The engineer in charge of the repairs used a very wet mixture, partly on account of the fact that the work was reinforced. This concrete has also disintegrated to a considerable extent, and is at present in much worse condition than the inboard section of the pier, on which no repairs whatever were made.

Here we have three specimens of concrete of similar ingredients, exposed to the same conditions, the only variable being the amount of water used in mixing. The very dry and the very wet concrete have been decidedly unsatisfactory. That of a medium consistency has successfully resisted disintegration under very severe exposure.

In another harbour along the North Atlantic coast are several miles of concrete quay walls, built during the past twenty years. Some of them were erected while engineering practice dictated that a minimum amount of water should be used in mixing the concrete ; some were built during the transition period when the amount of water was being increased, and those constructed since about 1905, especially those built recently, were of a much wetter consistency. All of these walls are of the same design and materials of the same quality were used throughout the work. The exposure conditions are practically the same in all parts of the harbour. All of the walls built prior to 1900, when dry mixed concrete was used, have disintegrated to such an extent that they have had to be frequently repaired and several sections entirely rebuilt. Those erected since 1905 of wet concrete with few exceptions have also been replaced on account of deterioration, or have needed a considerable amount of maintenance, but those built between 1900 and 1905, or during the time the concrete was made of a medium consistency, have needed no repairs at all and are found to be in excellent condition at present.

It is evident that the amount of water used in mixing concrete exposed to sea water action has a most important bearing upon the durability of the structure. *Either too dry or too wet a consistency will cause failure.* A medium consistency must be used if permanency is to be secured under severe exposure conditions.

The effect of thoroughness of mixing upon the quality of the concrete warrants more consideration by engineers, especially those engaged in designing sea water structures. Any expedient which makes for better concrete should be seized upon, for only the very best material can successfully resist the rigorous conditions to which structures in sea water are exposed. Up to a certain point there is a rapid and consistent increase in the strength of concrete with the thoroughness of mixing. The amount required to give the best results is dependent upon the conditions, such as type of mixer, proportions, consistency and character of materials.

Perhaps this phase of the subject will be made more impressive if put in this way. A better quality of concrete at less cost can be secured by omitting a considerable part of the cement and increasing the thoroughness of mixing.

CONCRETE MUST BE PROPERLY PLACED.

After the concrete is mixed comes the placing it in the forms. In this, especially, more difficulties are encountered in sea water work than in land structures, and yet only the best quality of work will be permanent.

Unless a cofferdam is built and the concrete placed in the dry, either a tremie or a bottom-dump bucket is used. Both methods have proved successful although the tremie is preferable if correctly operated. This, however, is far from a simple thing to do. Contrary to the supposition of many engineers, the concrete cannot be forced up above the bottom edge of the tremie for more than a few inches, even when the pipe is long and kept full. In order to start the flow the bottom of the tremie must be raised slightly so that the lateral movement of the concrete restrained by friction is permitted. As soon as the concrete starts to move it tends to discharge rapidly, owing to the combined hydrostatic and velocity head, and this frequently results in the loss of the charge—for a very nice balance must be maintained in order to control the rapidity with which the concrete leaves the pipe.

Of course a tremie should always be plugged when first charged ; otherwise a layer of separated stone, sand and cement mixed with a laitance will be deposited in the bottom of the forms, or a seam of such material made in the structure.

The bottom-dump bucket method possesses the disadvantage of permitting at least a slight settlement of the concrete through water and the precipitation of a small amount of magnesia on the surface of each batch. This will cause some laitance to permeate the mass, and may also cause some segregation. As with the tremie, successful results can be obtained only by the exercise of extreme care.

If the work below the low-water line is carried on intermittently trouble may occur unless particular precautions are observed thoroughly to clean the surface of the concrete previously deposited before the placing of concrete is resumed. This is what happened in a large pivot pier along the middle Atlantic coast. The depth of water in which the pier was built is about 45 ft., and the pier is 18 ft. in diameter.

It was intended to construct a cofferdam and place the concrete in the dry. Leakage through the bottom and sides caused this plan to be abandoned, and the concrete was deposited in the water by means of bottom-dump buckets. The work was carried on only during the daytime. Upon resumption of concreting in the morning no care was taken to clean off the surface of the concrete placed the day before ; in fact, the necessity for this was not even thought of. Of course the water covered it, and it was taken for granted a good joint would be secured between the days' work.

The cofferdam was left in place and it was not until a number of years after the work was completed that any apprehension was felt by the engineers as to the stability of the structure. By that time the planking of the cofferdam had rotted and enough of the boards had fallen away to expose a considerable section of the concrete. Only the part between high and low water could be seen. Here, however, the concrete had the appearance of a layer cake, with the soft material between the layers cut out to a considerable depth.

In order to determine the real condition vertical holes were drilled through a considerable depth of the pier. For about 6 in. the drilling was hard, then a soft section was struck, then a foot or so of hard material, then another layer of soft, and this continued to the bottom of the drilling. The soft sections were of varying thicknesses, some being as much as 24 in., while others were only about 6 in. thick. It was quite evident that these layers were formed between successive days' work. This pier is now in a serious condition and means will have to be taken soon to prevent failure.

A somewhat similar cause is responsible for a peculiar condition discovered in the supporting columns of a pleasure pier. In this case 18-in. riveted steel shells used as forms were sunk to the required depth, and the sand was pumped out. Water leaked in through the bottom, partly filling the shells, and concrete was deposited through this water. Here, however, the work was carried on continuously until the concrete was brought up to the elevation of high water—the shells being of sufficient length to reach to the deck. After the concrete reached the high-water line the forms for the beams and deck were built and concreting continued. As the deck was about 15 ft. above high water the supporting columns had to be extended this much.

No effort was made to clean off the surface of the concrete previously placed in the shells before the upper section was deposited. After the pier had gone through the winter an interesting condition was discovered in the supporting columns. It appeared as though the rivets in each shell for a distance of from 1 to 2 ft. near the elevation of high water had been cut out and the shell pried open at the joint. Some of these shells are shown in *Fig.* 25. This exhibited a cavity in the column which in some cases was as large as a man's head. Instead of concrete a soft

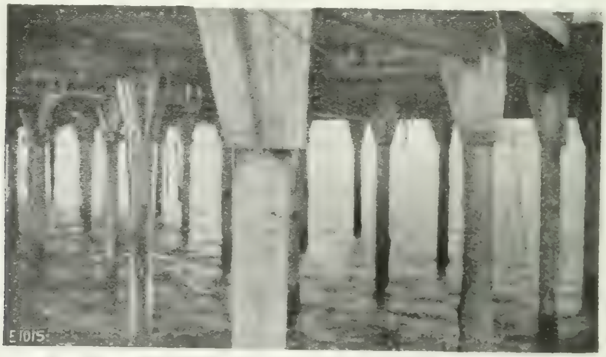


Fig. 25. Riveted Iron Shells forced open by freezing of moisture in soft material

chalky material was found. This had come to the surface as the shells were being filled to high water, and then it was covered when the filling of the section above the high-water line was completed. During the winter the moisture in this soft layer had frozen and burst the shells, and as soon as the steel protection was removed the waves washed out the soft material. Since then chemical disintegration of the concrete has progressed until many of the columns have failed completely and have had to be removed.

CONSTRUCTION SEAMS MUST BE PREVENTED.

For the work above the low-water line every precaution should be taken to prevent the formation of construction seams of laitance. If the tide rises and covers the section before completion of the work the surface of the concrete should be thoroughly cleaned by scrubbing with a stiff broom and washing with a hose before resumption of concreting.

In a harbour on the Pacific coast was found an interesting illustration of the value of extra precautions in this respect. Here there are a number of concrete sea walls built at different times but of similar design and materials. Although the specifications called for thorough cleaning of the surface of the concrete at construction joints, it was evident this was frequently not as carefully attended to as it might have been, for thin horizontal seams could be seen. (This is a criticism which applies to most of the concrete sea water structures along our coasts, for almost always the place where work was stopped due to the rising tide is conspicuous.) In one section of the walls just referred to, however, no construction seams could be found. The inspector who had been in charge during construction explained the reason for this. The contractor had covered the concrete with a canvas held in place with heavy weights whenever he had to stop concreting, so that a clean surface was found when the tide receded.

The simplest way to prevent disintegration at construction seams is not to have any such seams. If the work is done in short sections bulkheaded between the forms the concrete can be brought up faster than the tide rises.

While the concrete is being deposited it should be compacted so that the densest condition possible will be secured. If the proper consistency is used it will permit of light tamping, and under this treatment the concrete will quake and settle into a very compact mass, free from pockets and void spaces. The concrete next to the forms should be spaded so that a dense smooth surface will be secured, such a surface when exposed offering the greatest protection against the disintegrating action of the sea water. If it is firm, strong and tough, chipping and abrasion will be greatly lessened and the possibility of deterioration of the structure decreased.

Under many conditions a mortar face richer than the body of the structure will prove economical ; and where local materials are not of the highest quality this mortar surfacing can be made of imported aggregate of good quality, which if properly applied will protect the interior concrete made of poorer material.

It is impossible to apply a mortar coating to concrete after the forms are removed and have it adhere to that part of the structure below the high-water line, and it is between the elevations of high and low water that it is needed far more than anywhere else.

Many structures may be most economically built by using precast members. The concrete can be prepared and placed under far less difficulties, and it can be allowed to harden and cure thoroughly before being acted upon by sea water. But in precast work as well as work deposited in place, porous concrete, rough surfaces, leaky forms, and seams and joints will cause deterioration.

The practice of making precast piles of such length that a joint must be made between the elevation of high and low water, as shown in *Fig.* 26, should be discontinued. Often precast piles are found to be too short and have to be extended after they are driven. It is almost impossible by present methods to make a satisfactory joint between the elevation of high and low water. However, if a joint must be made at this elevation the utmost care must be exercised to clean the top of the pile before the concrete for the extension is deposited, and no leakage of the forms can be permitted if disintegration is to be prevented. The numerous structures which are showing signs of trouble at these construction joints give evidence that the need for the utmost care was not appreciated.

Deterioration of concrete structures in sea water is progressing in many places along all our sea coasts. When within a few years, or even months, a concrete structure costing hundreds of thousands of dollars shows marked signs of disintegration just because the necessary care was not exercised in its construction, it is time to sound a note of warning. Concrete can be used successfully in sea water, but the price of success is eternal care.

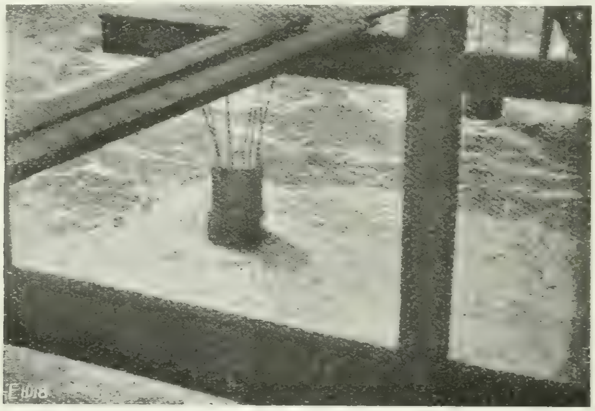


FIG. 26. LEAVING A JOINT SUCH AS TO BE MADE ON PILE IN CENTRE OF VIEW MAKES WEAK SECTION.

CONCRETE SHIPBUILDING IN FRANCE.

TUG-BOATS.

For the following particulars and illustrations we are indebted to Le Génie Civil, Paris.—ED.

One of the commonest objections to concrete barges is the allegation that if the shells are made reasonably strong they must be thick and heavy so that the proportion of dead—to live—load is unduly increased. Experience shows that this objection has been seriously exaggerated, and that in most cases it is based upon insufficient knowledge. In any case, it cannot apply to nearly so great an extent in the boats used for towing a series of barges, as such tug-boats do not carry any load other than their own engines, crew and a few spare stores.

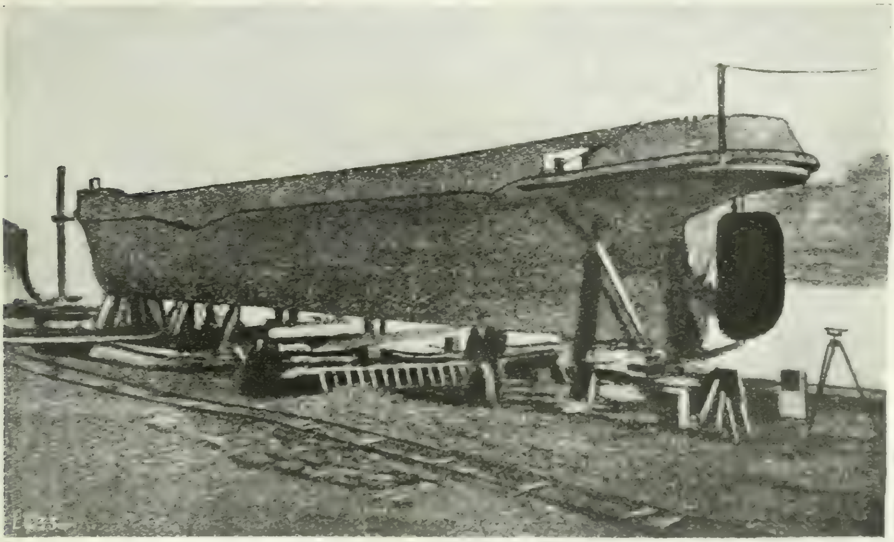


Fig. 1. View of completed Tug-Boat.
Concrete Tug-Boats in France.

On the other hand, tug-boats are much more liable to collisions with piers, pillars of bridges and other obstacles, and they must therefore be designed so as to offer the maximum of resistance. Reinforced concrete offers exceptional advantages for this purpose, and as the amount of vibration transmitted from the engines and propeller to the vessel is inversely proportional to the inertia of the mass of the latter, it will be seen that the use of concrete for towing boats is especially worth attention.

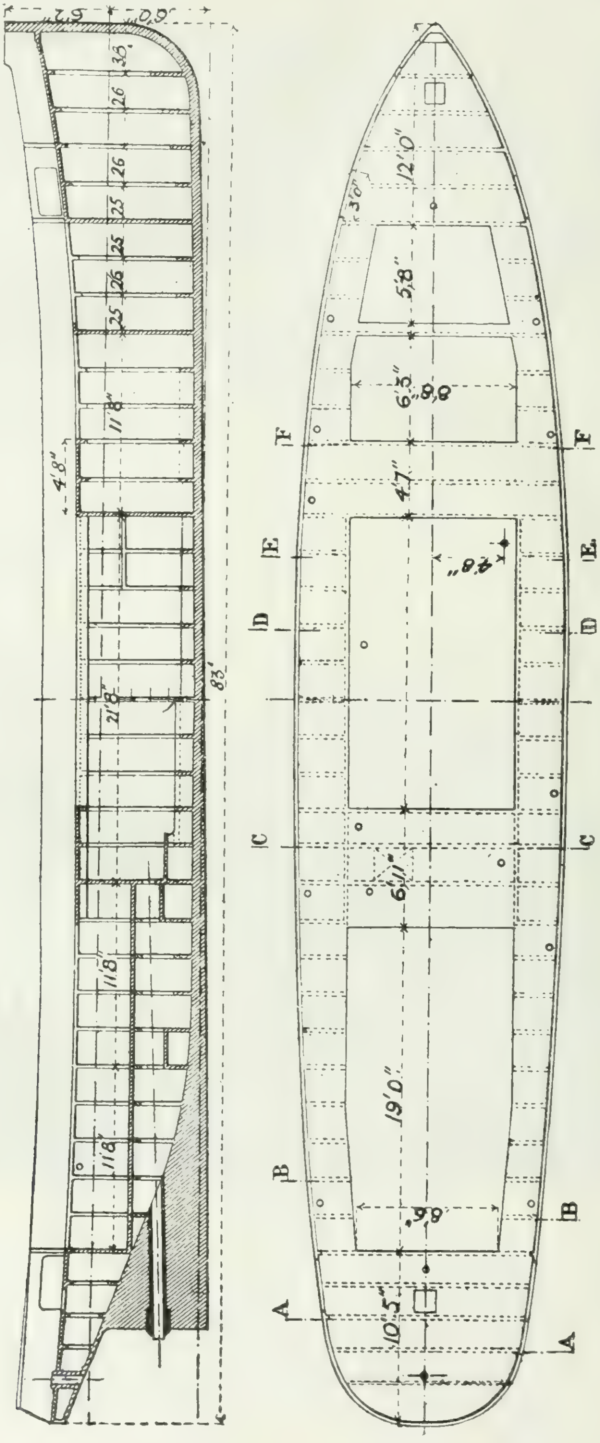


Fig. 2. Plan and Section of Tug-Boat.
CONCRETE TUG-BOATS IN FRANCE

A considerable number of towing boats is at present under construction in France, and the Société Pelnard-Considère, Caquot et Cie has already built fifty of these vessels, each of 300 h.p., on the banks of the Seine, near Paris, to the order of the Minister of Public Works. These boats are built in accordance with the regulations of the Bureau Veritas (the French equivalent of Lloyd's Registry) so as to be amply strong enough for river transport, with occasional short sea voyages. They are 83 ft. long with 17 ft. beam and 7 ft. deep, with a total weight (for the hull alone) of 68-75 tons and a displacement of 125 tons.

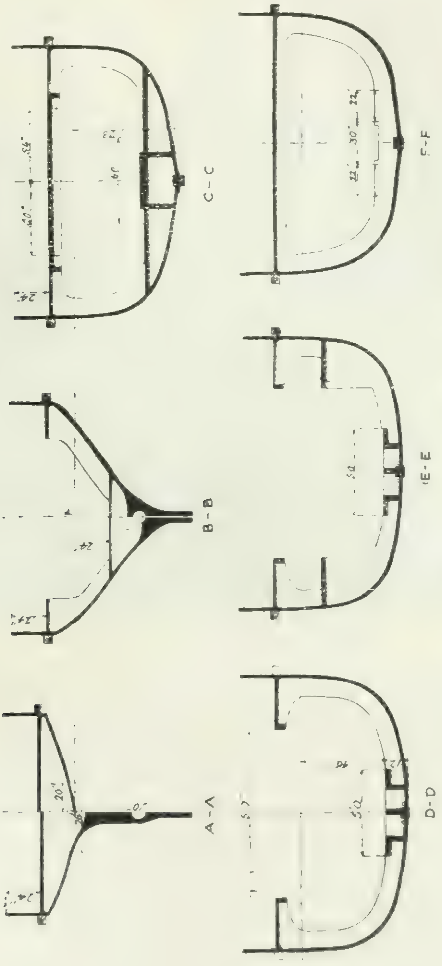


Fig. 3 Sections on line AA to FF in Fig. 2
Concrete Tug Boats in France.

They are designed so as to present a low resistance to the water, and their lines have been studied with special care, whereas in a barge this property is largely sacrificed in order to secure a large carrying power.

The interior is divided into six compartments—one for ballast, and usually containing the well for the chains, a second for stores, a third for fuel, a fourth for the engine or motor, a fifth for the crew, and the remaining compartment for ballast.

The hull has a series of ribs each 14 in. by $3\frac{1}{4}$ in. spaced 2 ft. 2 in. apart, surmounted by a rim $2\frac{1}{2}$ in. deep, the whole being stiffened horizontally by a series of slabs placed at different levels according to the position of the compartment in which they occur.

The deck has a thickness of $2\frac{1}{2}$ in. at prow and stern, $3\frac{1}{4}$ in. near the centre of the vessel, and 2 in. along the sides ; it is supported by ribs 10 in. high which fit the vertical ribs previously mentioned. In the deck are four openings measuring respectively 5 ft. 8 in. by 8 ft. 4 in., 6 ft. 3 in. by 9 ft. 10 in., 16 ft. 8 in. by 9 ft. 10 in., and 19 ft. by 9 ft. 6 in.

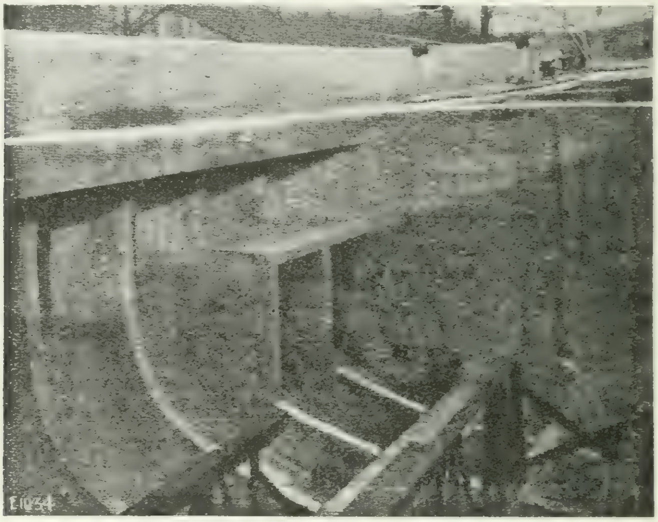


FIG. 4. Part of Interior showing ribs.
CONCRETE TUG-BOATS IN FRANCE.

The keel is of concrete with a steel casing. The stern is reduced to a simple support for the rudder and the propeller.

The concrete contains 45 to 50 lb. of cement per cu. ft. The estimated crushing strength is 800 lb. per sq. in., and the shearing stress 80 lb. per sq. in.

The mild steel used for the reinforcement has a tensile strength of 60 tons per sq. in., and a shearing stress of 48 tons per sq. in. The reinforcement is arranged in accordance with the system usually employed by M. Considère, stirrups being placed wherever the shearing stress is likely to exceed 70 lb. per sq. in. The engine beds and other foundations for the machinery were made at the same time as the corresponding portions of the vessel.

These vessels have been designed to withstand an external pressure of 500 lb. per sq. ft. at the rim without any allowance for their weight. A similar allowance is made for the body of the vessel. The dock is designed to carry a load of 200 lb. per sq. ft. In accordance with naval regulations, the vessel is calculated to withstand a longitudinal moment of flexion of $\frac{Pl}{30}$ where l is the length between perpendiculars and P its total weight.

A wooden fender 6 in. by 6 in. surrounds the vessel at deck level. It is attached in such a manner that if interchecked with any obstacle and subjected to great tension it will break away without damaging the vessel.

The builders are willing to undertake contracts to deliver ten of these boats per month, the first delivery to take place not more than three months after the receipt of order. They have hitherto been able to fulfil such engagements without difficulty.

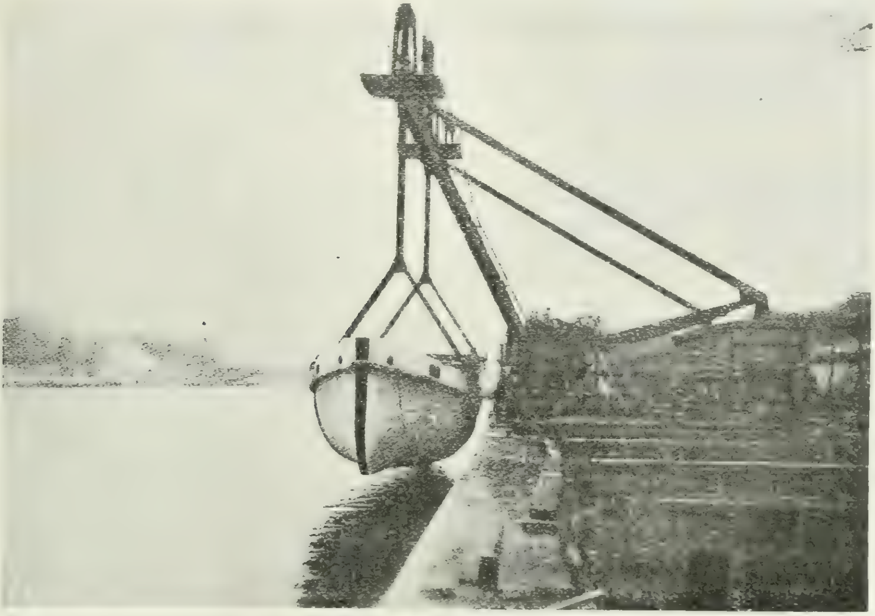
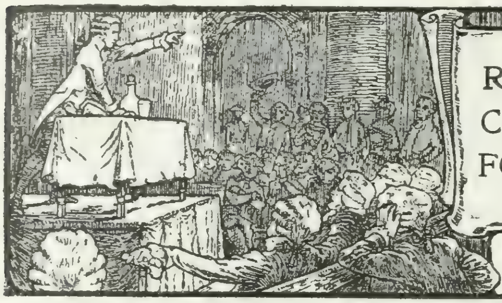


Fig. 5. Lowering the boat into the water

Concrete Tug-Boats in France.

The vessels being built on the banks of the Seine it is necessary to launch them with no disturbance to other traffic on the river. This is satisfactorily effected by means of a double crane, mounted on a single carriage, which travels on a track parallel to the river, and then runs to the water's edge on a short piece of track at right angles to the main one. The vessel is lifted bodily by means of movable stirrups attached to the arms of the cranes, and lowered gently into the water, its weight being counterbalanced by a large concrete box filled with gravel which is placed on the opposite side of the carriage.

The boats are fitted with two Diesel engines (aeroplane type), each of 150 h.p., or with a single engine of 300 h.p.



RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

AMERICAN CONCRETE INSTITUTE.

SOME PROBLEMS IN DEVISING A NEW FINISH FOR CONCRETE.

By JOHN J. EARLEY.*

REINFORCED concrete has long been justified structurally, but its appearance leaves much to be desired. In realisation of its shortcomings in this respect, and in consideration of the importance of a work that would give to concrete an appearance commensurate with its structural value, an effort was made to acquire an intimate knowledge of what had been done towards this end. The search was discouraging and on the whole without profit. No technique, applicable to the jobs under consideration, had been developed in the surface treatment of concrete. The evidence showed that appearance had been an afterthought, a secondary matter, a desirable but rather impossible thing which should receive all the consideration possible after the structural problems had been solved.

An analysis of the problem of appearance indicates three principal factors, namely, form, colour, and texture, all of which must be developed before reinforced concrete can be accepted by architects as a fitting medium for the expression of academic design. The degree in which reinforced concrete meets these three requirements is the measure of its liberation from its present restricted use. I hope that the time is not far distant when this view will be justified, when trained men will be meeting every requirement in form, colour, and texture that architects may impose: in other words, I hope to see the day when a rendered drawing will supplement the specifications for every reinforced concrete structure, and the structure will be a faithful expression of design.

About two years ago the United States, through the Office of Public Buildings and Grounds, built a retaining wall on the west side of Meridian Hill Park, Washington, D. C. This park is to be a beautiful and formal garden on the hill which marks the meridian of Washington, D. C. The original plans called for a reinforced concrete wall with a stucco finish, and certain decorative features which were to be cast in cement mortar and set in place. Extensive studies were made, including samples and full-size sections. Finally a unit of the wall was built in place, in concrete, complete in every detail excepting reinforcement. The result was a plastered wall, nothing more. The construction might just as well have been of brick, terra cotta, or metal lath on channel studs so far as the appearance revealed. The wall was without scale. It did not give the appearance of strength and size equal to its task as a retaining wall. The colour was unsatisfactory. It was the cold grey cement colour that has always been so objectionable. Every particle of sand was coated with cement and had no colour value of its own.

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* Architectural Sculptor, Washington, D. C.

An effort was made to relieve the monotony of appearance by finishing various details in different texture. The piers were built of rusticated blocks the surface of which was grooved vertically with straight, symmetrical, V-shaped grooves about $\frac{3}{8}$ in. on centres and $\frac{1}{4}$ in. deep. The coping and border of the wall panels were sand floated. The panels themselves were pebble dash in which the pebbles were as nearly as possible one size, having passed a $\frac{1}{4}$-in. screen and having been retained on a $\frac{1}{8}$-in. screen.

At this point it was decided to set aside the methods of finishing employed in the studies and full-size model and to use others that would be more characteristic of the wall construction. It was then suggested that the forms be removed while the concrete was yet green and the surfaces brushed with steel brushes until the aggregate was exposed. Permit me to emphasise in an especial manner that it was this decision to employ finishes characteristic of the nature of reinforced concrete that gave the interest to succeeding studies and resulted in the development of surface treatments as applied at Meridian Hill Park.

This method of treating the surfaces at once supplied the sense of strength and size that was lacking before. The wall was no longer a plastered one, but was reinforced concrete and nothing else, and it seemed big and strong enough to suit all the demands that would be made upon it.

A change took place in the colour. The surface, which had been wholly of a cement grey, was broken in frequent spots by clean pebbles in their natural colour which varied from white, to yellow, to light brown. The pebbles in a pile would be yellow. These spots relieved the grey of the cement to such an extent that they imparted to the whole structure a cream colour which was a great improvement and a decided step forward.

The exposed pebble texture was used on the wall panels, the face of coping, and the rusticated blocks of the piers. The borders around the wall panels, and rusticated grooves on the piers were finished differently. The forms were tooth-chiselled and the latter were left untouched. The reason this was done was to accent the drawing. It was feared that if the same texture that was used on the panels were used everywhere, the structure would have too rough an appearance and the drawing would be lost.

The forms for the piers were plaster, shellacked on the inside to make them waterproof, and so made that they would fit inside rough wooden forms which were depended upon to support the concrete. The forms for the panels were constructed of dressed lumber and followed general practice. Separate strips, channelled out on the back, were used to form the drip under the coping and the groove around the large panels. These strips were so arranged that they remained in place when the forms were removed and the shrinkage of the wood in drying was depended upon to release them.

A pier and a panel composed one unit and every other one was poured, then the ends were coated with five-ply felt and tar to form an expansion joint. This method was followed in order to give the first panels time to harden so that there would be less danger of breaking them when working on the adjoining panels.

The concrete mix was 1 : 2 : 4. The cement was a standard brand passing the tests of the Bureau of Standards, the sand was fairly clean river sand of the size known as concrete or torpedo sand, namely, everything that passed the $\frac{1}{4}$-in. screen on the dredge. The pebbles were of good quality, hard and reasonably uniform ; the largest passed a $1\frac{1}{4}$-in. mesh and were retained on a $\frac{1}{4}$-in. mesh ; however, the great bulk were, in size, such as would pass a $\frac{3}{4}$-in. mesh. This concrete was poured into the moulds and its consistency was soft, so soft that it would flow readily.

After 24 or 48 hours, according to the condition of the cast, the forms were removed and the surfaces scrubbed with a steel brush until the aggregate was exposed as evenly as possible. The entire unit was then thoroughly washed with water from a hose. The seasoning was carefully watched and frequent wettings were used to prevent too rapid drying.

The cast cement trimmings were what is known as dry pressed castings, that is, one part of cement and $1\frac{1}{2}$ parts of coarse sand are moistened so that the material will hold its shape when pressed together but not so wet that water can be squeezed from the mortar. This mortar is then tamped into plaster piece moulds which can be removed immediately. These castings when well made are very sharp and clean, conforming to every requirement of form, but their colour and texture is limited to the colour of the cement and the texture of the sand. From the foregoing an idea may be gained of the problem presented by the first retaining wall at Meridian Hill Park and how the conditions were worked out. The accompanying photographs will illustrate the character of its work, showing clearly how the conditions of form and texture were met, and while the colour is not recorded this requirement was complied with about as well as were those of form and texture.

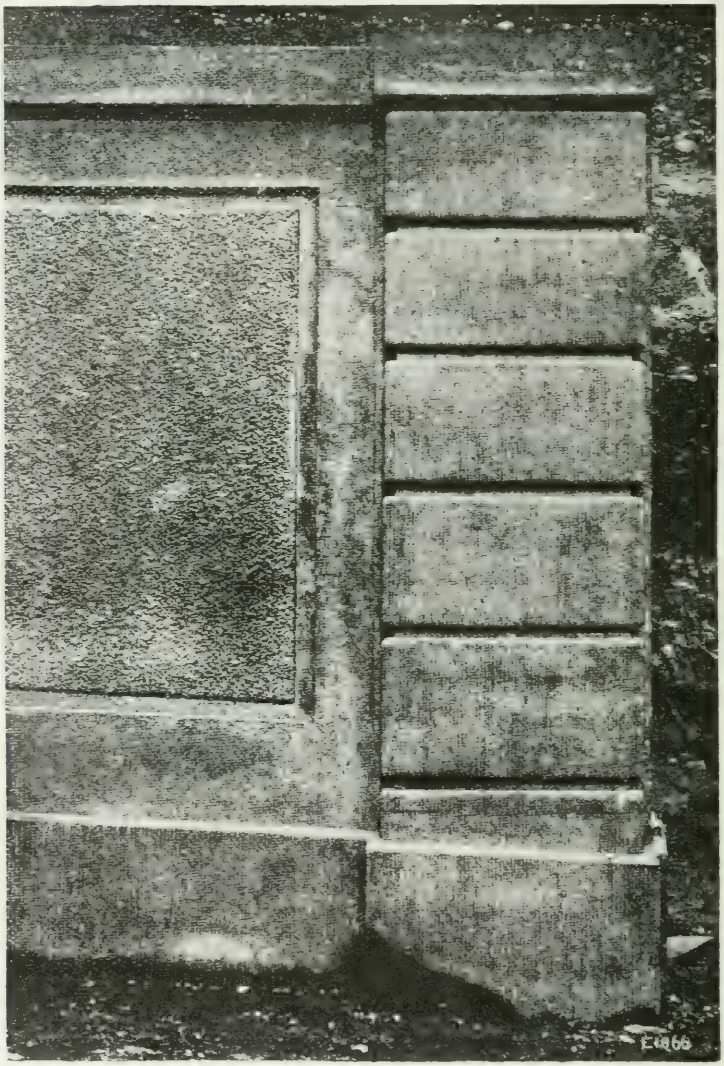


FIG. 1. REINFORCED CONCRETE WALL WITH STUCCO FINISH AND PRECAST RUSTICATED PIER WITH VERTICAL GROOVES FOR TEXTURE.

It has the cold grey cement colour of ordinary concrete. The textures are conventional and not characteristic of concrete.

The second operation at Meridian Hill Park consisted of a balustrade 300 ft. long located on the upper level of the park, and an arched entrance with a flight of steps connecting the upper level and the street.

The technical progress made in the execution of this work and the great improvement shown in the results were largely due to a careful study and severe criticism of the first operation. So radical were the changes in methods and materials that I feel that I must pause here to make sure the criticism I am about to make of the first operation will in no way belittle it in your mind; for the first operation stands in no need of apology. It is a thoroughly satisfactory concrete retaining wall, rather better than was expected at the start, and while the second operation shows marked improvement, it is only a reasonable progress and must not detract from the merit of the first.

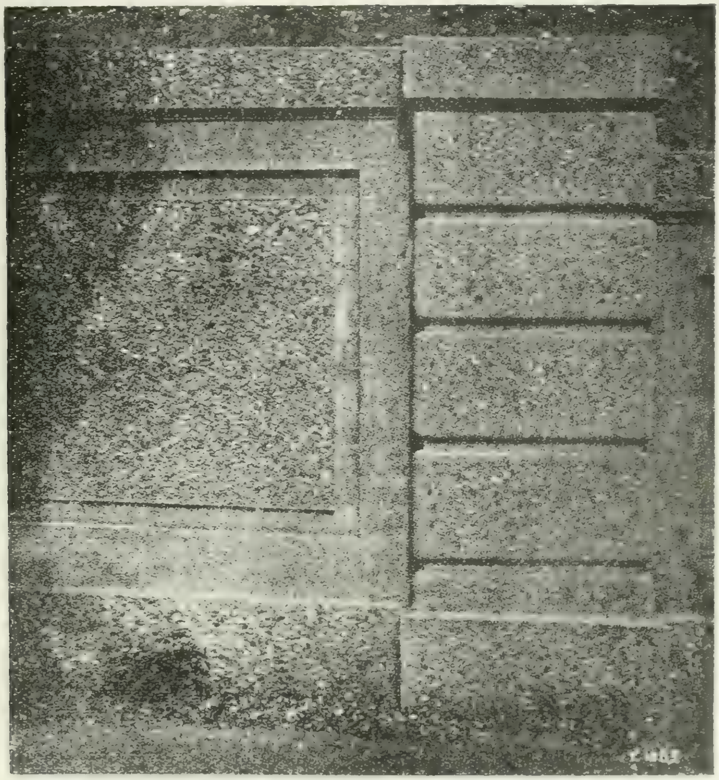


FIG. 2. REINFORCED CONCRETE WALL AND PIER SIMILAR IN DETAIL TO THAT SHOWN IN FIG. 1.

Texture and colour obtained by exposing aggregate. Note that the surface treatment is characteristic of concrete, as opposed to that in Fig. 1.

At the opening of this paper I spoke of the desirability of reinforced concrete being made to meet any requirement of form, colour, and texture that the architect may impose. I had been encouraging the architects in this belief and the second Meridian Hill operation certainly reacted vigorously. The 300-ft. balustrade was detailed without restriction. The entrance was a classical arch flanked by pilasters and surmounted by a complete entablature. In designing no concession was made to the material, but every requirement of form was insisted upon. The photographs show the sharpness of line and the refinement of contour that characterise all the details. The same method of surfacing was employed as on the first wall; namely, that of removing the forms while the concrete was green and scrubbing the surfaces with a steel brush. A change of texture was made to accent the drawing, but in this case the effect was obtainable by changing the grain of the texture rather than by changing the nature of the texture.

The forms for the balustrade and arch were an art in themselves and the difficulties encountered were most discouraging. Morning after morning the previous day's work was broken up and thrown away. Sometimes the average was one cast out of five, sometimes a little better. In the beginning it was only a great faith in the truth of the theory that kept us at work.

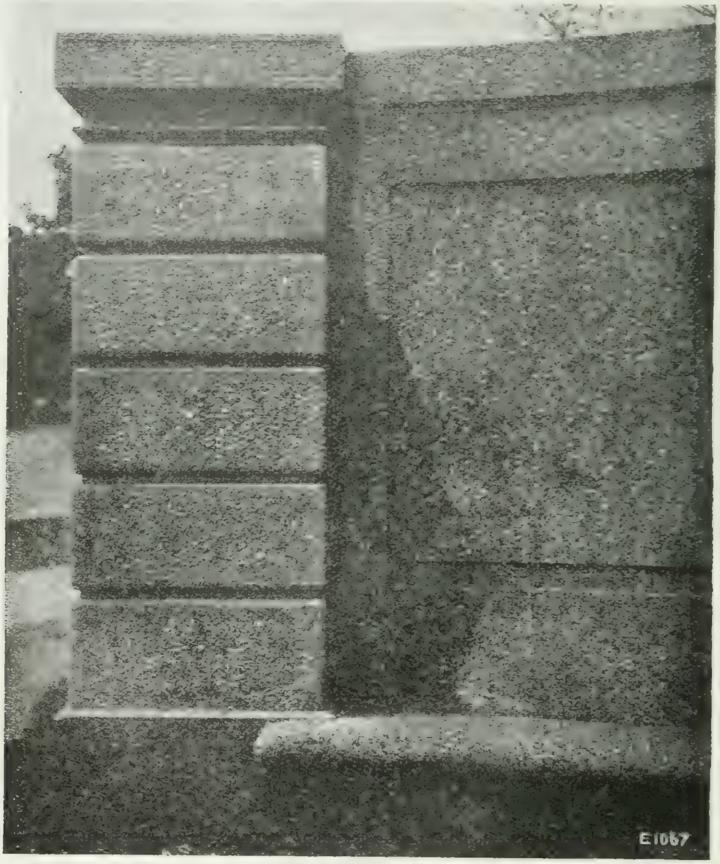


Fig. 3. Pier and Wing Wall at Entrance to Park, showing Junction between First and Second Operations.

Note the decided improvement in surface treatment of the wing wall, seat, and pier cap, as compared with that of the pier. In the latter the matrix predominates, in the former the aggregate.

In order that you may understand let me illustrate one difficulty. For certain reasons it is necessary that the surfaces of all important moulds be waterproofed. This produces, between the wet smooth surface of the cast and the impervious surface of the mould, what the shop men describe as "suction," and when large surfaces are involved the suction is great. If the casts could be allowed to harden this suction would be of little consequence, as the strength of the concrete would be sufficient to overcome it. But when the concrete is to be surfaced green the mould must be removed at a time when the suction of the mould and the strength of the concrete are about in equilibrium. Consequently, instead of the mould coming off clean, large spots of concrete stick to it and spoil the cast. I have in mind some time to continue these papers showing how the moulds were prepared, how the concrete was mixed and placed so as to overcome this and other difficulties. Suffice it to say that shop technique has improved to such an extent that a cast is seldom lost. Do not, however, think that all the troubles have been overcome and that these methods are perfected. Quite the contrary is true; the work has just begun.

The first wall was of a cream colour obtained by exposing the aggregate; the yellow spots were made to break the surface and the light reflected from them gave a sense of colour. It naturally suggested itself that to improve the colour a more careful selection of aggregate be made. Great care was taken in looking for and choosing the aggregate, which was finally located in the neighbourhood of Washington through a local sand and gravel company whose co-operation was a great help.

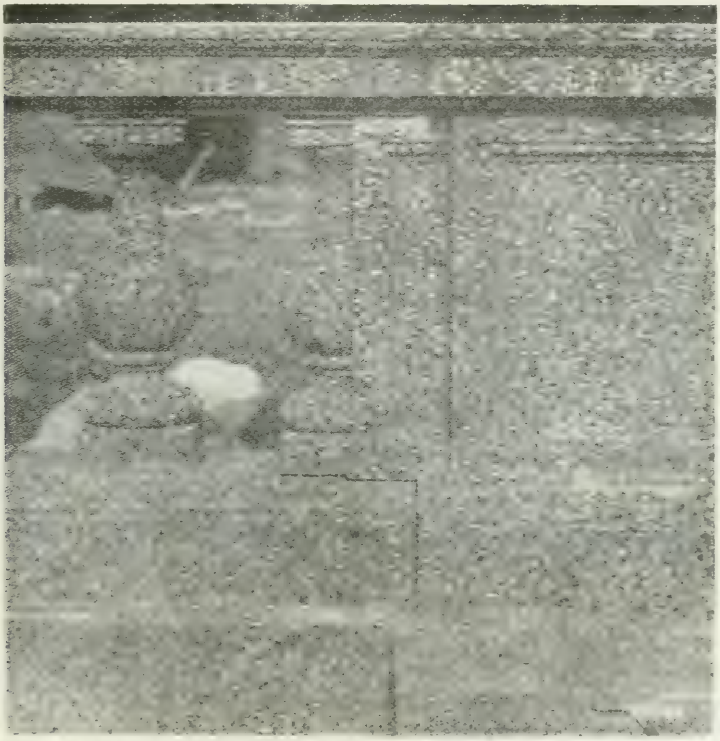


Fig. 4. Architectural Design of Balustrade, Unrestricted as to [illegible]

This concrete has met every requirement in form, colour, and texture.

When the aggregate had been chosen the next most important influence on the colour of the work was the frequency with which the spots appeared on the surface. The arbitrary 1 : 2 : 4 mix had to be abandoned and another formula evolved which would deposit the particles of aggregate in the mould as closely to one another as possible. The frequency with which the spots appeared on the surface was principally influenced by the composition and the consistency of the concrete; by the care with which it was placed; by the uniformity with which it was mixed; both as regards the proportioning of the ingredients and the length of time it was allowed to remain in the mixer.

Experience has demonstrated to my satisfaction that the colour of architectural concrete (I use the term for want of a better) must be that of a tone obtained by the disposition of small contrasting spots in uniform proportions over the whole surface. Pastelles are a familiar example of this theory of colouring. These surfaces which assume a tone are, upon examination, found to be lines of blue, red, yellow, green, etc., hatched and cross-hatched until they give the effect of uniform colouring. They have an irridescence and a brilliancy which lends to them a charm all their own. And so it is with concrete : it is a medium with a charm all its own, which by its nature suggests the pastelle scheme of colouring as opposed to that of solid tints such as are obtained from a coat of paint. I do not think it is possible for satisfactory tints to be obtained in concrete by the addition of pigment to the mortar. I feel that this method is contrary to the nature of the medium. The efforts that I have made in this respect have, without exception, resulted in flat muddy colours.

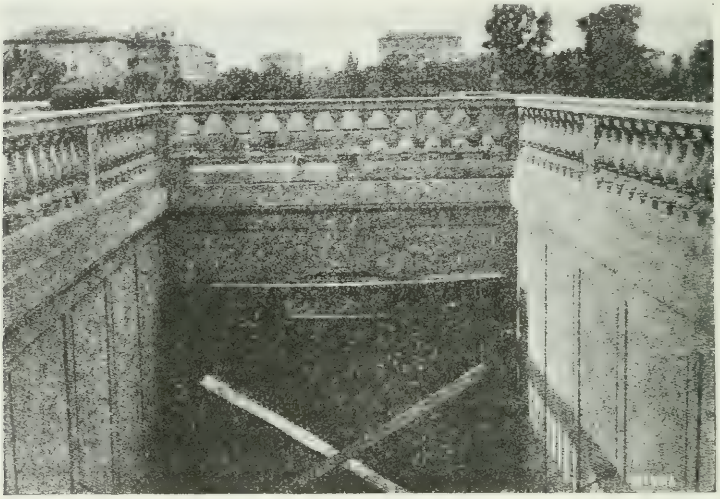


Fig. 5. View of Open Stairway from above, indicating Character of the Work.

The third requirement, that of texture, showed as great an improvement in the second operation as did the colour. It was decided that the best way to the desired effect was to abandon the 1 : 2 : 4 mix. The fact that the colour and the texture were so closely dependent upon the same method of proportioning greatly simplified the work to be done on the concrete. Many samples were made employing different sizes of aggregate, different size of sand, and different proportions of the ingredients, especially water. Let me impress the fact that, of all ingredients that enter into concrete, none require more exact care in proportioning than the water. Too much or too little water affects the colour and the texture through its effect on the arrangement of the pebbles and the case with which the casts are surfaced.

When the aggregate is exposed on concrete surfaces the planes and lines should not be irregular and lumpy, showing many stones in one place and few in another, but should rather be uniform and true, conforming perfectly to the contours of architectural detail. The surfaces should have many uniform particles lying closely together, as the scales on a fish, true and even of surface, yet presenting many irregular planes to the play of light and shade.

My desire is to have you realise that concrete as a plastic medium is capable of expressing architectural detail from the simplest to the most elaborate, is able to meet the most exacting requirements of texture, and is subject to beautiful colouring dependent for its range only on our knowledge of aggregates.

An architect friend of mine in lecturing to his class prophesied that structural concrete because of its adaptability to lintel construction and its plasticity would, within a few years, revolutionise building construction and so influence architecture as to found a new school.

Let us not try to find appearance in a concrete into which appearance has not been built. If we do we are doomed to failure. But on the other hand let us build refinement into concrete so that this great material may find a beauty worthy of its strength.

MEMORANDUM.

The Permanent Way Institution.—At the invitation of the Concrete Utilities Bureau, of 6 Lloyds Avenue, E.C.3, an interesting visit was paid on Saturday, September 21st, by fifty members of the Permanent Way Institution (London Section) to the collection of concrete products on view at 143 Grosvenor Road, S.W. The visitors were primarily interested in the articles especially designed for use on the railway, of which there are in the collection a considerable number, contributed by the Great Western Railway, London and South-Western Railway, Great Northern Railway, North-Eastern Railway, and the Cheshire Lines Committee. The examples of concrete sleepers naturally came in for a good deal of attention, and several interesting discussions arose as to the merits or otherwise of the different types exhibited.

The interest of the members, however, was by no means confined to railway matters, and the descriptions of the numerous other illustrations of the uses of concrete were attentively followed.

During the afternoon those present were enabled to see carried out a series of tests on $2\frac{3}{4}$-in. cubes of neat cement and others gauged with three parts of standard sand. The results clearly indicated the great margin of safety there is in well-made concrete when submitted to a crushing or compressive trial.

At the close of the proceedings, which had been admirably organised by Mr. E. Treacher, the visitors expressed their appreciation of the opportunity which had been afforded them for an inspection of the various examples of concrete products and an interchange of ideas concerning them.

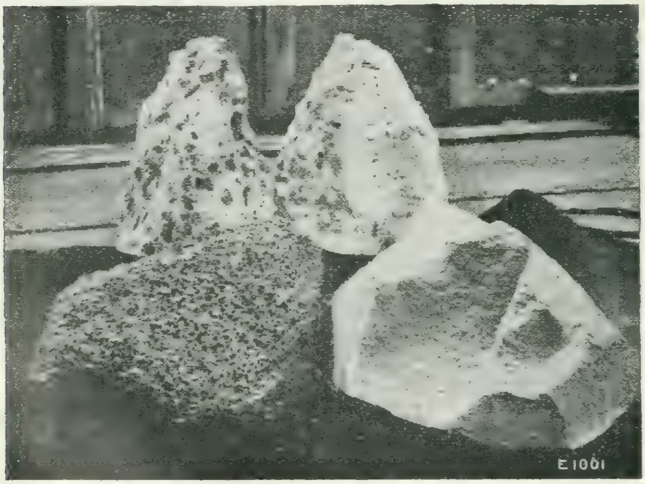
LIGHT WEIGHT CONCRETE FOR SHIPS FROM SPECIAL AGGREGATE.

Volcanic Rock Forms Basis for Concrete of High Strength and Weight Twenty per cent. Lighter than Normal.

By JAMES P. NASH,
Testing Engineer, University of Texas, Austin, Tex.

Reprinted from "Engineering News Record."—ED.

TESTS recently made in the laboratory of the engineering division of the bureau of economic geology. University of Texas, show that certain aggregates, notably a volcanic scoria readily available in the South-West, will give concretes of weights about 120 lb. per cu. ft., and in 28 deg. tests compressive strength above 4,000 lb. per sq. in. Such material would have marked and obvious advantages for concrete ship building.



IN LEFT FOREGROUND—NEW MEXICO VOLCANIC ROCK. RIGHT FOREGROUND—QUARTZITIC SANDSTONE. CONCRETES FROM ROCK IN REAR.

The volcanic scoria used in these tests is from New Mexico, about thirty-five miles north of Las Cruses. Crushed between ¾ in. and ⅛ in. in size it weighs but 39 lb. per cu. ft. loose. The specific gravity of the material being 1·50, it weighs solid 93·4 lb. per cu. ft. The volcanic rock screenings passing the ¼ in. screen weigh 78 lb. per cu. ft. loose. This increase in weight of the screenings over the crushed rock is due to the fact that considerable pore space is lost by the finer crushing. Sandstone used in the tests, though somewhat heavier than the volcanic rock, also gave good results. It came from the property of the Texas Gravel and Sand Co., at Piedmont, Grimes County, Texas. An up-to-date crushing and screening plant able to produce 200 tons of crushed and screened stone per day is in operation, so that no further development is necessary to assure a constant supply for ship construction. From the fact that this material is only eighty miles from the port of Houston, Tex., it is believed that it offers numerous possibilities for the construction of concrete ships.

TABLE I.—CHARACTERISTICS OF AGGREGATES USED IN TESTS.

Material.	Specific gravity.	Weight lb. per cu. ft. solid.	Weight lb. per cu. ft. loose.	Absorption per cent.	Crushing Stg. lb. per sq. in.	Percentage retained on ¾ in.	½ in. screens	¼ in. screens	⅛ in.
Volcanic scoria	1·50	93·4	39	4·2	From 1,500 to 5,000	2	62	94	98
Indurated sandstone ..	2·20	137·0	61¾	3·4	5,410	0	40	71	100
Limestone	2·62	164·0	78	1·4	9,860	0	—	100	—
Colorado river gravel ..	2·59	—	61½	—	—	0	40	70	100

The rock has a specific gravity of 2·20, giving a weight solid of 137 lb. per cu. ft. Crushed so that it will pass the ¾-in. screen and be retained on the ¼-in. screen, it weighs 61¾ lb. per cu. ft. Screenings passing the ⅛-in. screen with the dust removed weigh 62 lb. per cu. ft. Due to a smaller porosity, the sandstone screenings weigh less than do the screenings produced from the lighter volcanic rock.

The mixing and placing were done by hand, and the same consistency was obtained in every case except where noted in the tables. This was a mushy consistency; that is, when the concrete was tamped with a ⅝-in. rod water would appear on the top of the soft concrete. The specimens were 6 in. by 12 in. cylinders, which were stored twenty-one days in wet sand, and then in air until tested. Where sand is noted the local Colorado river sand was used. This is a well-graded coarse sand of excellent quality for concrete work. The gravel specimens were made from the local Colorado river gravel, except the gravel was graded to conform with the grading of the sandstone. The crushed limestone also approximated the grading of the volcanic rock, so that the results are directly comparable.

TABLE II.—Results of Tests of Concrete Suitable for Shipbuilding.

(Each compressive strength result is the average of from two to four specimens.)

Coarse Aggregate.	Fine Aggregate.	Proportion.	Water used per cent. by Weight of Mix.	Sacks of Cement per cu. yd. of Laid Concrete.	Weight of Concrete, lb. per cu. ft.	Compressive Strength lb. per sq. in.		Remarks.
						7 days.	28 days.	
Volcanic rock, ⅛ to ¾ in.	Sand passing ¼ in. screen	1 : 1 : 2	16·4	11·1	124·0	—	5,100	
Volcanic rock, ⅛ to ¾ in.	Sand passing ¼ in. screen	1 : 1 : 2 10 per cent. hydrated lime by weight	18·4	10·4	120·8	—	4,100	More water used in this mix than necessary.
Volcanic rock, ⅛ to ¾ in.	Volcanic rock screenings, below ¼ in.	1 : 1 : 2	19·8	11 4	119·7	—	5,060	
75 per cent. volcanic rock, 25 per cent. limestone, ¼ to ¾ in.	Sand passing ¼ in. screen	1 : 1 : 2	15·1	10·9	129·0	—	4,525	
Crushed limestone, ¼ to ¾ in.	Sand passing ¼ in. screen	1 : 1 : 2	12·8	10·2	140·5	—	4,500	
Sandstone, ⅛ to ¾ in. ...	Sand passing ¼ in. sieve	1 : 1½ : 3	13·1	7·57	132·0	1,730	3,560	
Sandstone, ⅛ in. to ¾ in.	Sand passing ¼ in. sieve	1 : 1 : 2	15·3	10·4	131·75	2,140	4,100	
Sandstone, ⅛ to ¾ in. ...	Sandstone screenings between ⅛ in. and No. 48 sieve	1 : 1 : 2	15·3	10·75	128·75	2,785	4,990	
Gravel, ⅛ to ¾ in. ...	Sand passing ⅛ in. sieve	1 : 1 : 2	10·7	9·43	143·0	2,770	4,450	
Sandstone, ⅛ to ½ in. ...	Sand passing ⅛ in. sieve	1 : 1 : 2	16·7	10·0	130·25	1,505	3,340	Too much water used in mixing
Sandstone, ⅛ to ½ in. ...	Sand passing ⅛ in. sieve	1 : 0·6 : 2·4	15·6	10·45	130·0	2,350	4,775	

It is worthy of note that both the sandstone and the volcanic rock concrete are superior in strength to the gravel and limestone concrete at twenty-eight days. In the case of the volcanic rock and screenings the concrete weighs 14·8 per cent. less, and has 12·5 per cent. more strength than the limestone concrete made at the same time and similar in every way. In like manner the concrete made with the crushed sandstone and screenings weighs 10 per cent. less than the similar concrete made with gravel and sand and at the same time developed 12·4 per cent. greater strength. The weights for the concrete given in the tables are the weights of the concrete when it is removed from the moulds twenty-four hours after being poured. With the sandstone concrete the weight at twenty-eight days was approximately the same as the one-day weight, the water absorbed in wet sand being given up when the specimens were stored in air. The volcanic rock concrete, however, averaged about 1 lb. per cu. ft. heavier than at one day.

Using the sandstone crushed below the ⅛-in. screen and screenings of the same material, a concrete has been produced which weighs but 128 lb. per cu. ft. The strength of this concrete has not yet been determined, so the results are not recorded. In fact the above results are only preliminary to a larger series of tests of this same material, which will include absorption tests and modulus of elasticity determinations.

CORRESPONDENCE.

Under this heading we invite correspondence.

To the Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

SIR,—The interesting paper by Messrs. Johnson and Kingston, and your editorial comments thereon in your September issue, raise some questions which are of great importance at the present time, when concrete is being so largely employed for shipbuilding, a use which demands the highest possible quality of material. Whilst some of the conclusions of Messrs. Johnson and Kingston may be open to objection, their main point, that the best mixture cannot be obtained by using arbitrary proportions such as 1 : 2 : 4, seems to me to be unassailable. The ideal concrete, taking into account strength, impermeability and economy, is one in which the aggregate is so completely graded as to leave a minimum of voids, the cement forming a film uniting the particles of the aggregate. Down to a certain small limit, the thinner this film the greater is its adhesive strength. A badly-graded aggregate leaves a large proportion of voids, and the resulting concrete is porous, unless sufficient cement be used to fill the interstices which should have been filled by the finest particles of the aggregate A simple and familiar illustration will make the principle clear. A cask filled with cricket balls, shaken down as closely as possible, is still capable of holding a quantity of marbles, and, after as many marbles as can be shaken down into the interstices have been added, there is still room for a quantity of small shot. If a solution of glue were now to be run into the cask, the mass would be rendered solid when the glue had set. The adhesive material would then be distributed through the contents of the cask in the form of a thin and fairly uniform film. This would give nearly the maximum strength of which a glue-aggregate concrete is capable. The actual maximum would be attained if the aggregate, instead of consisting of spheres of three different sizes, contained spheres of all diameters between that of the cricket balls and that of the smallest shot used, mixed in proportions which may be determined mathematically.

The ideal aggregate should be of this character. It should contain particles of all dimensions between the largest and smallest, mixed in such proportions as to fill space completely. The cement then forms a thin film coating each particle, and is able to exert its maximum adhesive power. Evidently such an ideal mixture is not to be arrived at by the use of an arbitrary ratio of the constituents, such as 1 : 2 : 4. In practice, no aggregate will be so perfectly graded, and a certain excess of cement must be allowed in order to fill the remaining voids, but it is usually possible, by an examination of the coarse and fine aggregate, to determine the best proportions in which to use the materials available. The authors of the paper have shown one way in which this may be approximately done. It is to be hoped, however, that some of our laboratories will undertake the granulometric analysis of a number of aggregates prepared in various ways from known materials, and perhaps devise a method by which the test may be readily carried out.

The papers on concrete in sea water by Messrs. Wig and Ferguson, which you have been printing recently, emphasise the importance of the above point. These authors describe cases of failure which are no doubt often to be attributed to defective workmanship or to faulty materials, but they have made it clear that a concrete intended to resist the chemical action of sea water must be as dense as possible, and this can only be effected by a proper grading of the aggregate. To use a badly-graded aggregate and to trust to the use of an excess of cement to fill up the voids is undesirable when the concrete is to be immersed in a solution, such as sea water, which is capable of acting chemically on the products of setting of the cement

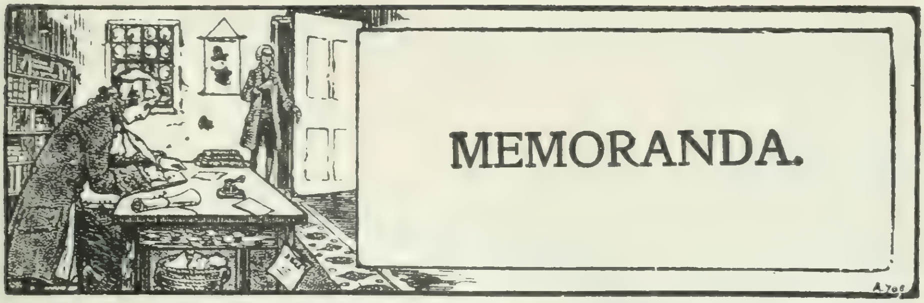
It is true that, as stated in your editorial note, the quantity of water used in making the concrete has an important influence on the strength, but the optimum proportion may be determined by experiment, and either a wetter or a drier mixture gives inferior results. The manner in which the concrete is to be set in place determines to some extent the degree of wetness to be aimed at.

It would be of interest to have the opinions of your readers on the points raised in these articles.

I am, Sir, yours,

CECIL H. DESCH

Royal Technical College, Glasgow.
September 23rd, 1918.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Training Classes for Disabled Officers.—The Cambridge University Board of Architecture has organised training classes for architects, craft students, builders, land agents, and those interested in the practical or historical sides of artistic training. These classes are for the benefit of disabled officers, and are directed by Professor E. S. Prior and Professor Beresford Pite. Every facility for study, elementary or advanced, is offered, the classrooms and laboratories of the university being thrown open to the students, for whom workshops for practice in building craft are available as well as facilities for experimental work in the physics relating to building materials, for studying the science of concrete construction, and for instruction in practical forestry.

The Cambridge Board of Architectural Studies is undertaking also a series of experiments in limes and cements at the instance of the Department of Scientific and Industrial Research, and has set up a special committee formed from the University staffs of engineering, forestry, geology and chemistry. The results will in due course be available for the architectural profession. There are contemplated further researches in aggregates and the best forms of reinforced concrete. The co-relation of the laboratory with the practical experiments of building is intended for the general benefit of the building trades.

Concrete Roadways in American Encampments.—The accompanying illustration, taken from the *Concrete Highway Magazine*, shows a concrete main thoroughfare at Camp Dodge, near Des Moines, Iowa. The writer in the above magazine states that, " Although subjected to extremely heavy use, these pavements show no signs of wear. From 6,000 to 8,000 vehicles per day pass over the 18-ft. pavement, including the proverbial steel-tired mule wagon and the heavily laden motor-truck. During the construction period of 1917 40,435 ft. of pavement were laid. Construction was continued during 1918, and up to the middle of June 12,000 sq. yds.

Concrete on main thoroughfare in Camp Dodge, near Des Moines, Iowa.

had been laid. . . . The concrete was a 1 : 2 : 3 mix, the thickness 6 in. at the sides and 8 in. at the centre, and joint spacing was on the average 40 ft. apart. . . ."

Concrete Kerbing.—At a recent meeting of the S.E. district of the Institution of Municipal Engineers a paper was read by Mr. W. N. Taylor, borough engineer and surveyor of Aylesbury, on "Aylesbury and its Municipal Works," and in the course of his paper the author made a short reference to concrete kerbing, which we give below, as follows :

"Concrete kerbing and channelling had been used in Aylesbury for about seven years, and over 3,000 yds. had been laid. It was made by the Council's workmen and had proved satisfactory and was suitable for any of the roads in the town, except on hills, where it might be unfairly used by drivers of vehicles running the wheels against the kerbing. At first wooden moulds were used, but after a time these were discarded in favour of iron moulds. The section of the kerbing was 5 in. by 10 in. deep, in lengths of 3 ft. It was slightly tapered at the top and rounded. The tapering was to avoid a cart wheel damaging the whole of the face. The section of the channel blocks was 9 in. wide by 4 in. deep, in lengths of 15 in., and was slightly dished on the surface. The channelling when laid was protected by a row of 4 in. by 4 in. stone setts. The aggregate for the kerb and channel blocks was in the proportion of one of Portland cement to three of ¼ in. to dust Clee Hill granite chippings. The kerb and channelling were always laid on a bed of Portland cement concrete 4 in. in thickness and bedded with cement and sand. The cost of making the kerb was 7d. per lin. ft. and the channel 4½d. per lin. ft., and when laid complete on 4 in. of concrete cost 2s. 9d. per lin. ft."

Concrete Roads.—French Roads after the War—According to a writer in *Technique Moderne*, France has something like 372,800 miles of roadways, and it seems that steps are being discussed to meet the demands of increased fast motor traffic by the formation of reinforced concrete roads, and there is talk of a Consultation Committee to devise the best plan of roadmaking, looking to the nature of the future traffic and to determine in what way it may be possible to secure the requisite funds for the purpose.

Hydro-Electric Power, Canterbury, N.Z.—In connection with the development of hydro-electric power in Canterbury, N.Z., a large power house has been erected entirely in reinforced concrete ; it is 180 ft. long, 70 ft. wide, and 40 ft. high. This structure is built complete to house the whole 12,000 kw. plant in connection with the scheme of development.

Economy in the Design of Concrete Buildings.—In the Journal of the Boston Society of Civil Engineers (June, 1918) appear some particulars of experiments made by Mr. F. S. Bailey, with a view to ascertaining the most economical mixture of cement, sand and aggregate. The principal tests made were : the comparative costs per 100,000 lb. compressive strength, of different mixes with three kinds of aggregate, viz., hard sandstone, broken stone and gravel, and comparative costs with different mixes with beams or slabs of different depths. The conclusion arrived at by the author was that excepting in one instance the experiments went to prove that a mix of 1 : 2 : 4 would be most economical.

Concrete Ships in England.—We learn from the daily Press that two concrete sea barges were launched on September 21, one in the north and another in the south of England. The barges are 187 ft. 6 in. long by 31 ft. 6 in. beam, by 20 ft. 9 in. deep, and contain three holds for cargo in addition to adequate accommodation for captain, crew, machinery and stores.

British Concrete Shipbuilders.—An organisation to be known as the "Conference of British Concrete Shipbuilders" has been established with the object of discussing technical and other matters of mutual interest, and the provision of facilities for collective dealing with the Department of the Controller-General of Merchant Shipbuilding. Mr. J. S. E. de Vesian is the Chairman of the Conference.

Concrete Ship Association.—According to the *Engineering News Record*, an International Concrete Ship Association has been formed in New York for the purpose of furthering the interests of concrete ship construction. The offices for the time being are at 7 E. 42nd Street, New York. The annual subscription is to be not exceeding 500 dollars for Corporations and 25 dollars for individual members.

Spain.—In a previous issue we made reference to Spanish reinforced concrete vessels, and were able to present illustrations of the first Spanish reinforced concrete boat in course of construction by the Sociedad Anonima Construcciones y Pavimentos. We have now received two further illustrations of this vessel completed, before and after launching. It will be recalled that this boat was more in the nature of an experiment, but the successful tests to which it has been submitted have led the above company to erect further ships of 1,200 tons, which are being constructed at their large yards at Malgrat.

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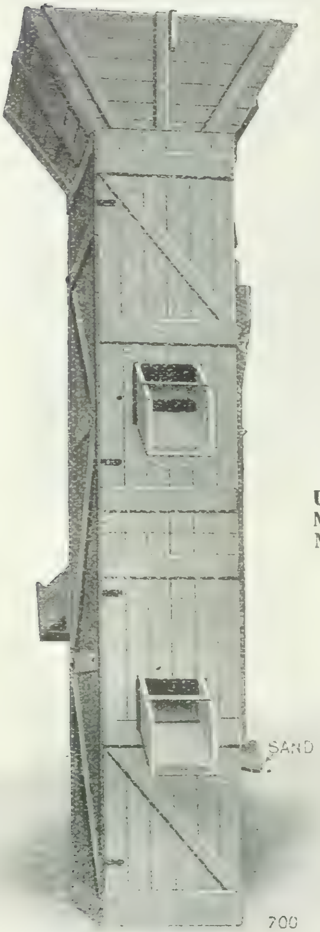

Capacity :
20 yards per hour.

○

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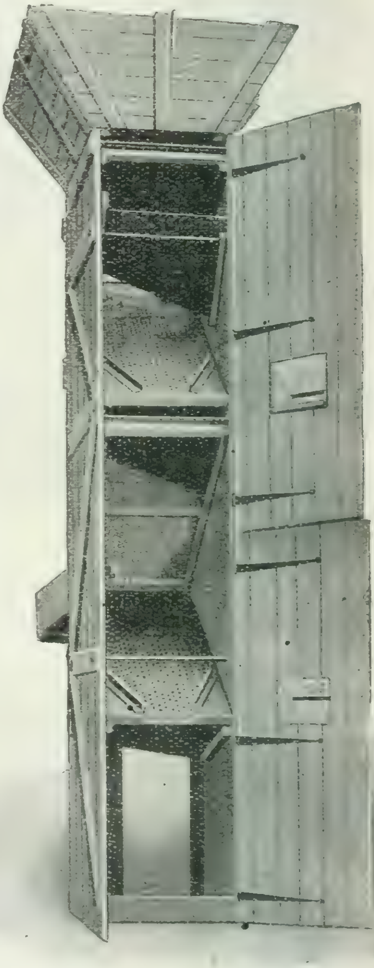

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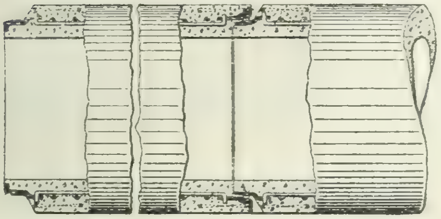
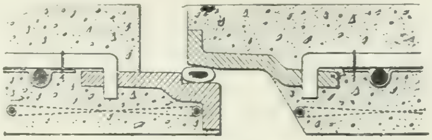
Reinforced Concrete Vessel at Singapore.—Messrs. Brossard, Mopin & Co., of Singapore, have recently completed the construction of a reinforced concrete ferry-craft which has been launched at Tanjong Rhoo. The vessel is to be used as a ferry vessel to convey goods wagons of the railway across the Johore Straits. The craft is 120 ft. long, 27 ft. beam, and 3 ft. moulded depth. Dead-weight capacity is about 230 tons. The boat is built entirely of reinforced concrete, with the exception of a part of the deck, which is teak wood. We hope to present an illustration of this ferry-craft in a later issue.

Concrete Pipe Joint designed for High Pressure.—A pipe joint capable of standing very high heads, forming an expansion and a universal joint and applicable to concrete pipes of sizes as low as 4 in. in dia., has been developed by the Lock Joint Pipe Co., New York City.

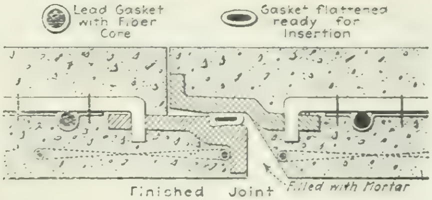
The fundamental principle consists in the use of a special lead pipe gasket which squeezes against the cast pipe ends when the pipes are drawn together and forms a water-tight joint which at the same time permits a certain deformation of the pipes themselves without affecting their tightness.



Longitudinal Section of Jointed Pipe



Before placing Pipe together


Lead Gasket with Fiber Core
Gasket flattened ready for Insertion
Filled with Mortar

Finished Joint

The gasket is of specially made lead pipe of size varying with the size of the pipe to be jointed, and is fitted with a fibre core which ensures continuity of surface when the pipe is flattened and squeezed. Where concrete pipes are used, the pipe ends are of specially shaped castings which are placed in the forms before the concrete pipe is poured and, being fastened to the reinforcement of that pipe, become integral with it when the concrete sets. Two pipes are brought together by a screw jacking arrangement extending back to the last pipe already in place in the tins. In tests made in the yard the pressure on 4 in., 9 in. and 36 in. pipe, the pressure was put on up to 110 lb. per sq. in., and the pipe moved through a considerable amplitude under this pressure without showing a leak.—*Engineering News Record.*

Defective Concrete Piles. In preparing the ground for a harbour at Nieuwediep, near Leidain, in August, 1916, a number of piles were used which proved deficient in various respects. In some the heads were seriously damaged because no provision had been made for protecting them during the action of the pile-drivers.

In other piles the reinforcing bars broke at some distance from the head and the spiral reinforcement also snapped. This was attributed to the core of the pile being too hard with respect to the outer portions and to minor irregularities in mixing. A well-illustrated description is published (in the Dutch language) in *Gewapend Beton* August, 1918 (L. J. Veen, Amsterdam).

Hollow Blocks.—An improved hollow brick of cement has been invented at Stockholm. The characteristic feature claimed for this brick, which is called "Terma," is that an air channel has been arranged in the joints, whereby an effective utilisation of the air as an insulating material in outer walls has been attained. A company has been formed for exploiting the invention.—*Contract Journal.*

Publications Received.—*Proceedings of the Engineering Association of N.S.W.* (Vol. XXXII., 1916–17). The above volume, which has just come to hand, contains a number of interesting papers, amongst which may be mentioned: The Microscopy of Steel; Concrete Shipbuilding; Notes on Improving the Efficiency of Fuel Economisers; Notes on Estimating and Costs of Architectural and Engineering Works, etc., etc.

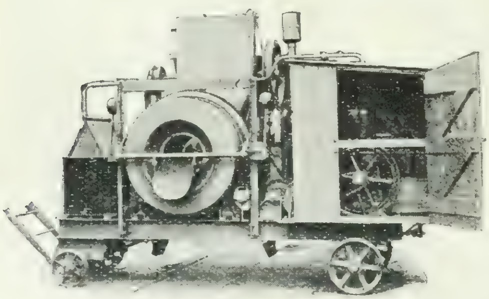
TRADE NOTE.

Capt. Scharroo, of the Military School of Engineers in Holland, has contributed to a Dutch magazine a very interesting article relating to the waterproofing of Portland cement with "Pudlo." After giving a brief explanation of the various methods of waterproofing cement, he states that he found both liquids and powders generally affected the cement adversely. He was, therefore, very sceptical about the outcome of his experiments with the powder "Pudlo." The results, however, were so successful and surprising that in the interests of the Dutch building trade he decided to publish the results.

Reference is made to some tensile and compression tests made with Pudloed concrete by Messrs. Koning & Bienfait, the Dutch cement experts, and from these Capt. Scharroo's experiments are confirmed that "Pudlo" makes cement perfectly impervious without detrimentally affecting the cement. He urges the use of Pudloed cement in the construction of concrete ships.

Capt. Scharroo's article is the first of a series, and we look forward to his further remarks with interest.

The Dutch agent for Messrs. Kerner-Greenwood & Co., Ltd., of King's Lynn, the makers of "Pudlo," states that Capt. Scharroo is a well-known expert on cement, and that the publication of his experiments in the Dutch technical paper, *Gewapend Beton*, is causing many enquiries from other authorities.



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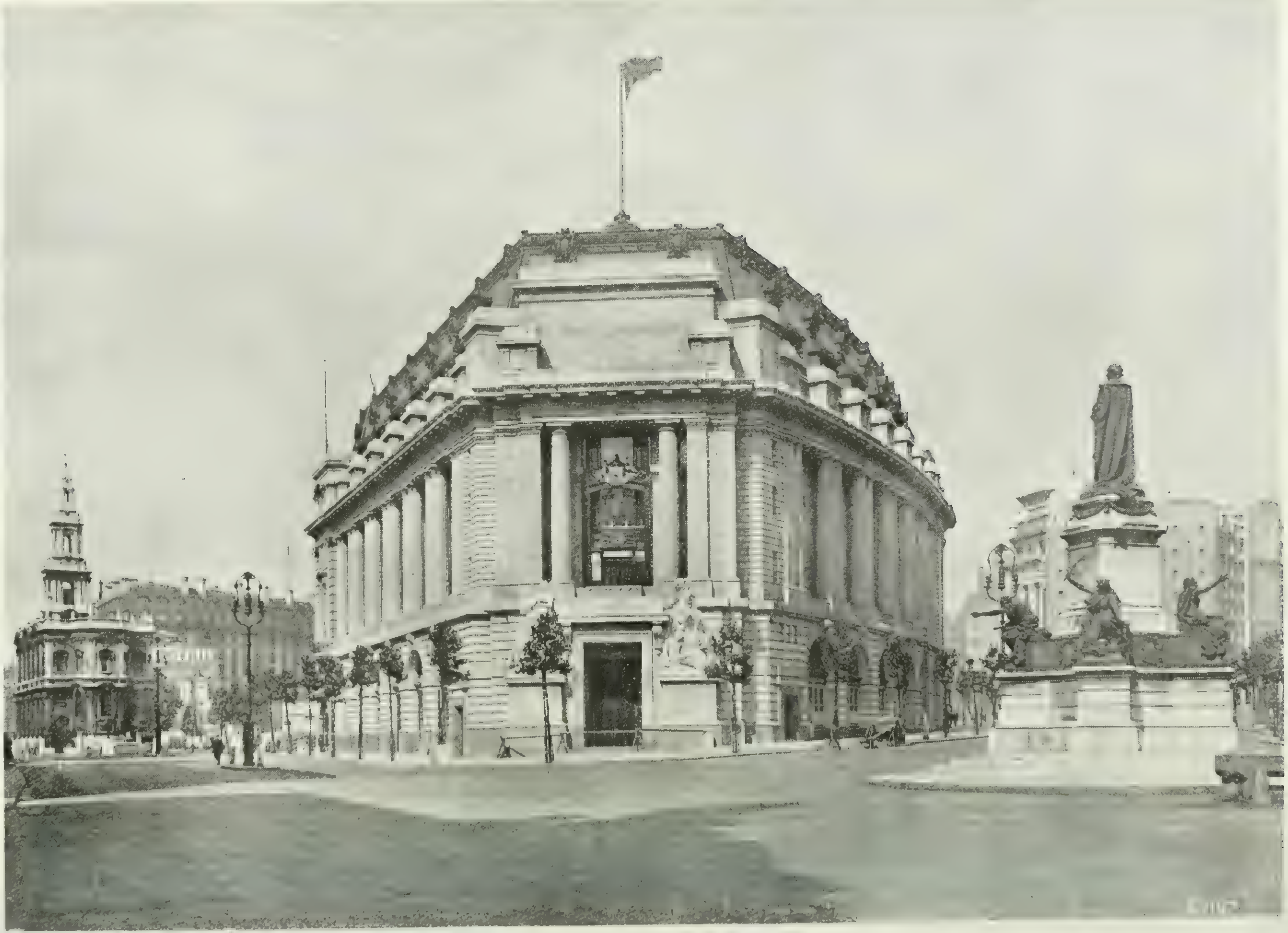


Photograph by Bedford Lemere.]

Fig. 5. **View of Finished Building from St. Clement Danes.**

Australia House.

(For Description see page 559.)

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XIII. No. 11. LONDON, NOVEMBER, 1918.

EDITORIAL NOTES.

CONCRETE SHIPBUILDING.

WITH this issue we publish the first of a number of "special supplements" in which it is proposed to deal with concrete shipbuilding and its developments to date, as far as it has been possible to gather this information.

The growing importance of this branch of concrete construction, together with the keen interest that is being shown in the subject, lead us to believe that these supplements will meet with a great need and will be useful to our many readers at home and abroad.

Special care has been taken to make the information as complete as possible, though, naturally, under present war conditions, it is not possible or advisable to publish very detailed particulars as to the most recent designs evolved in this country.

The first supplement touches upon the question of the Need for a New Material, owing to the shortage of steel and timber, and in Chapter II a brief history of concrete shipbuilding is given ; this historical survey will be completed in the December issue. Later supplements will deal with such questions as "Materials used in Concrete Ship Construction," Design, Workmanship, etc.

FIRE PROTECTION IN SHIPYARDS.

WE desire to call attention to a letter we have received from an eminent surveyor, which we publish on page 598 of this issue, regarding the fire hazards in shipbuilding yards where concrete ships and barges are in course of construction. There is not the least doubt that, owing to the extraordinary rush due to the belated decision to build concrete ships and barges, the shipyards have not been laid out with a due regard to the risk of fire, which is particularly hazardous where there is such a large storage of timber and where so many woodworking operations prevail in the preparation of the forms and shuttering necessary for this type of ship construction. And although, of course, it may be excellent, after the shipyard has been devised and has been got into working order, to lay down external hydrant mains and to provide first-aid fire appliances, such equipment cannot in the slightest degree be compared with the value of a proper lay-out and construction and a suitable equipment, arranged for at the outset, from the fire point of view. Prevention is obviously better than any possible cure, and it is to be hoped that those who have control of these shipyards will insist on such precautions being taken as are now still possible in the preventive sense, and where the proprietors of the yards have not taken the elementary precautions in the separation of hazards the essential structural divisions should be put in hand to meet the grave hazards evident to the veriest tyro in these matters.

As the writer of the letter very truly indicates, the mere fact that the finished ship or barge is of concrete does not reduce the fire hazard of the yard.

CONCRETE ROADS.

ONE of the most important questions that will arise during the reconstruction period which will follow the conclusion of the War is that of the rebuilding of many of our roads and the making of new highways both in this country and in the war-devastated areas of the Continent. The use to which the roads will be put—the nature and amount of the traffic—will be amongst the factors governing the material to be adopted in their construction, and whatever other materials are employed, there are indications that both here and in France concrete will undoubtedly be used for some of these new roads. We have in these pages made repeated reference to its extensive use for this purpose in the United States, and we have also been able to publish illustrated articles of such roads in this country. We believe, also, that, during the period of War concrete has been further tried for the roadways in several of our large encampments and has been subjected to heavy motor traffic. As has been pointed out by writers in these pages, the success of the concrete road is dependent upon the care bestowed in its construction, and for this reason we would like to call the special attention of our readers to two papers read on the subject of concrete road making at the annual meeting of the American Concrete Institute this year. We publish one of them in the current issue, and hope to reproduce the other next month. Both papers are indicative of the thoroughness with which every detail in connection with concrete road making is being studied in America, and we trust the authorities in this country may be led to take up the matter in an equally complete and exhaustive way.

CONCRETE WORK IN TERRITORY EVACUATED BY THE ENEMY.

Now that the Allied troops are going over the ground so long occupied by the enemy, in which all manner of structures of concrete and reinforced concrete have been erected, the time has surely come when a representative panel should be appointed by the authorities to examine the way in which concrete has been applied by the enemy, not only for purely military purposes and as a safeguard against bombing, but for general purposes of military and civil engineering. There cannot be the least doubt that there is a considerable amount to be learned in these areas as to the use to which concrete has been put on such an extensive scale by the enemy, and as soon as the necessary particulars have been taken by a thoroughly representative and competent panel the results should promptly be made available for the use of the technical professions in this country.

PUBLISHER'S NOTE.

THE above-mentioned supplement on Concrete Shipbuilding will be issued free with each issue, or it can be obtained separately, on application, at a cost of 1s. 1d. (post free).

AUSTRALIA HOUSE.

One of the most important and interesting buildings completed during the war is undoubtedly the new Commonwealth building, of which we are able to give some particulars in the following article by courtesy of the architect, Mr. A. G. R. Mackenzie.—ED.

In these days of war, when the whole of the Colonies have hastened to the defence of the Mother Country, it is fitting that their official centres should occupy prominent positions in the metropolis, and this building, which was recently opened by H.M. the King, occupies one of London's finest sites, and is symbolic of Australia's desire to stand for all that is implied by the phrase, "Unity Within the Empire."

The position of the building is the eastern portion of the Strand-Aldwych site and is, as will be seen from the plan (*Fig.* 1), almost triangular in form, each of the three frontages being about 190 ft. long, but at the apex, where the Strand and Aldwych meet, the corner is cut back to a width of about 40 ft. to form the main entrance. The site was offered by the London County Council to the Commonwealth Government in 1909, but it was not until 1911 that the purchase of the whole freehold was agreed upon.

In February, 1912, Mr. A. Marshall Mackenzie and Mr. A. G. R. Mackenzie were selected to carry out the work of designing a building that should epitomise Australia and express its importance in the capital of the Empire. The building was required to include a large Exhibition Hall suitable for the display of the products of Australia and also to provide accommodation for the offices of the Australian State Governments. A reference to the plans (*Figs.* 1 and 2) shows how well the architects have solved the problem before them, and the unbroken vista of nearly 200 ft. from entrance to furthest extremity of the Exhibition Hall is a worthy example of "grand manner" planning and is in keeping with the broad lines and dignified appearance of the exterior.

The foundation stone for the building was laid in July, 1913, and for a time progress was rapid. Labour troubles and the outbreak of the war soon, however, began to delay progress, and although many Government regulations were waived with regard to this structure it was not until the end of 1916 that any portion of the building could be used.

The elevations, which are of Portland stone on a base of Australian trachyte, are described by the architects themselves as having a foundation in the Roman architectural style modified by certain eighteenth century French *motifs*. The more successful features are :—

1. The effect in the mass as the building is approached, especially from the east, and at points where its proportions and contours are fully in view.

2. The colonnades on the Aldwych and Strand sides.

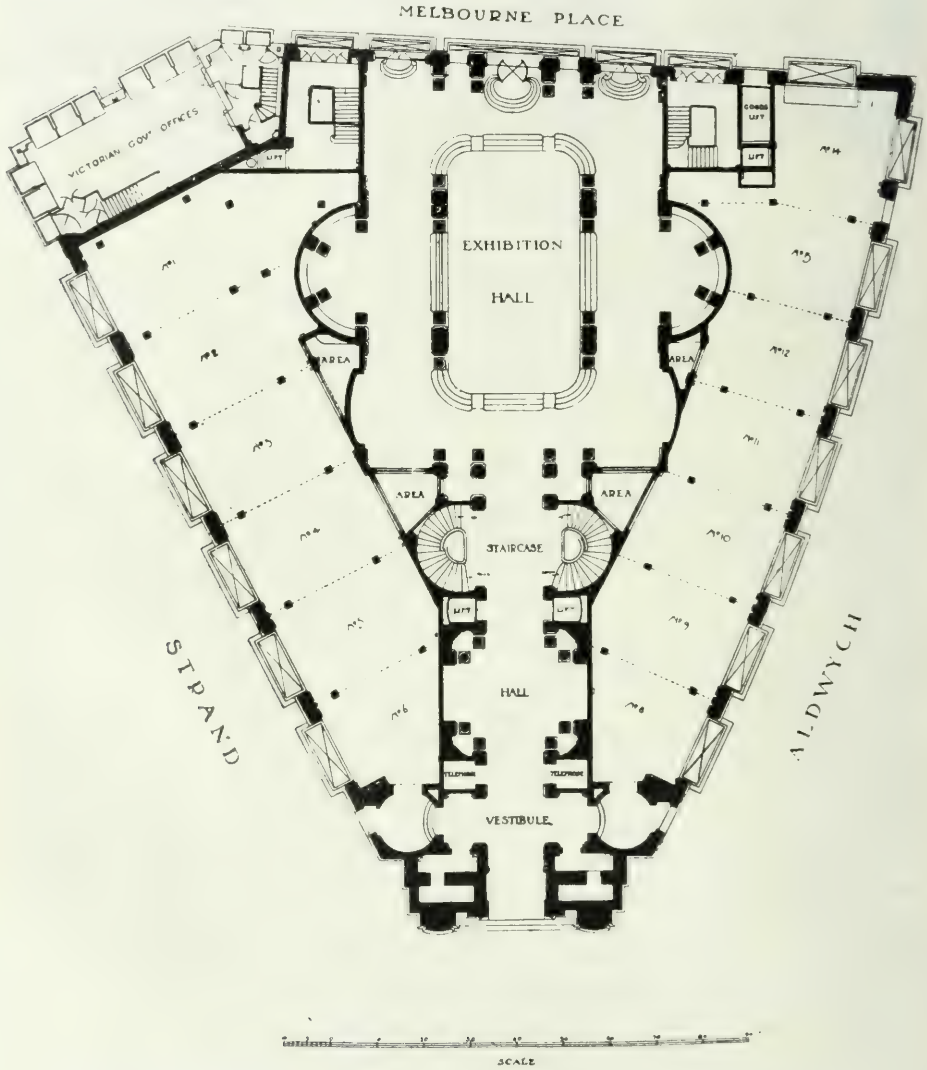


Fig. 1. Plan of Ground Floor.
AUSTRALIA HOUSE.

3. The curving sweep on the north-eastern façade, in which the configuration of the site on its Aldwych side has been admirably developed. The unstinted solidity allowed to the walls, moreover, has given full play to the columns of the façades in the matter of the light and shade of the exterior composition, whilst

another feature worthy of note is the dignified treatment of the roof of the building, in which an elaborate design carried out in copper finely harmonises with the stone of the substructure.

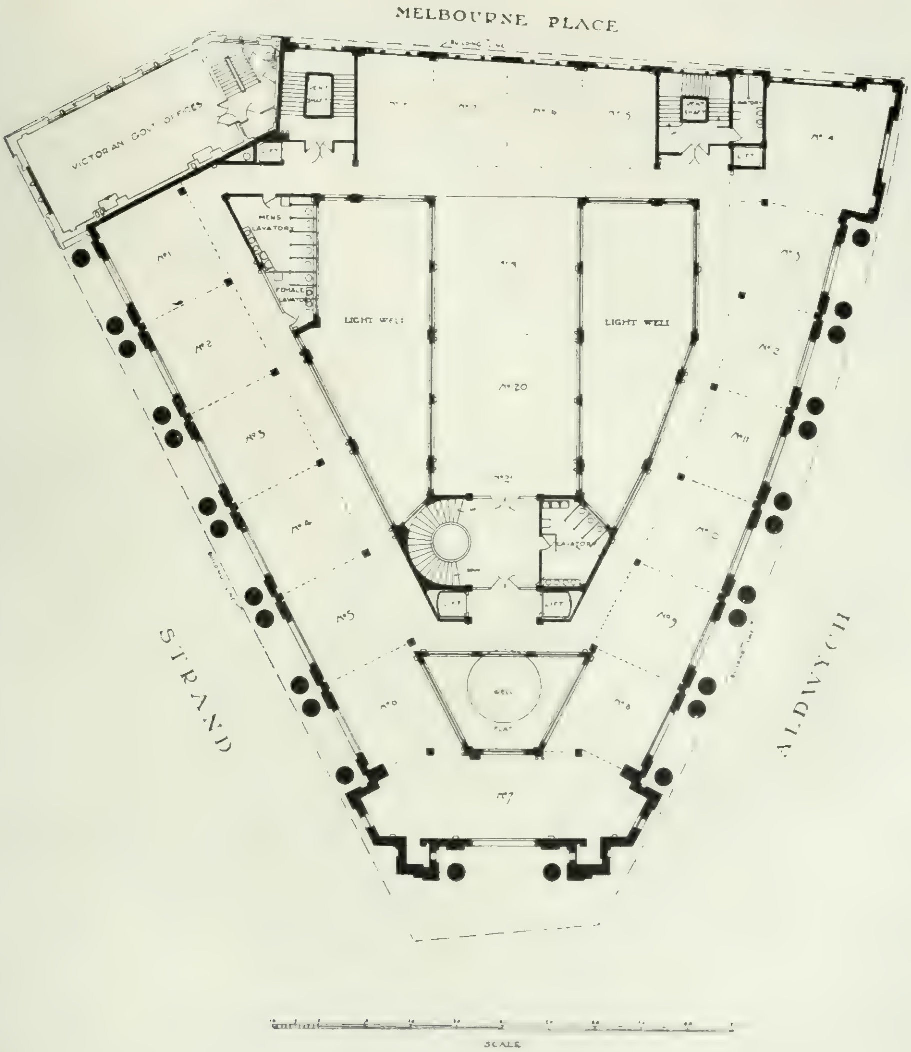


Fig. 2. Plan of Upper Floors.
Australia House.

Within the building Australian products have been widely used, and marbles from the Australian quarries at Buchan, Caleula and Augustan form the basis of the decoration of the Exhibition Hall and its approaches; and on each of the upper floors a different Australian wood has been used for the floors and fittings

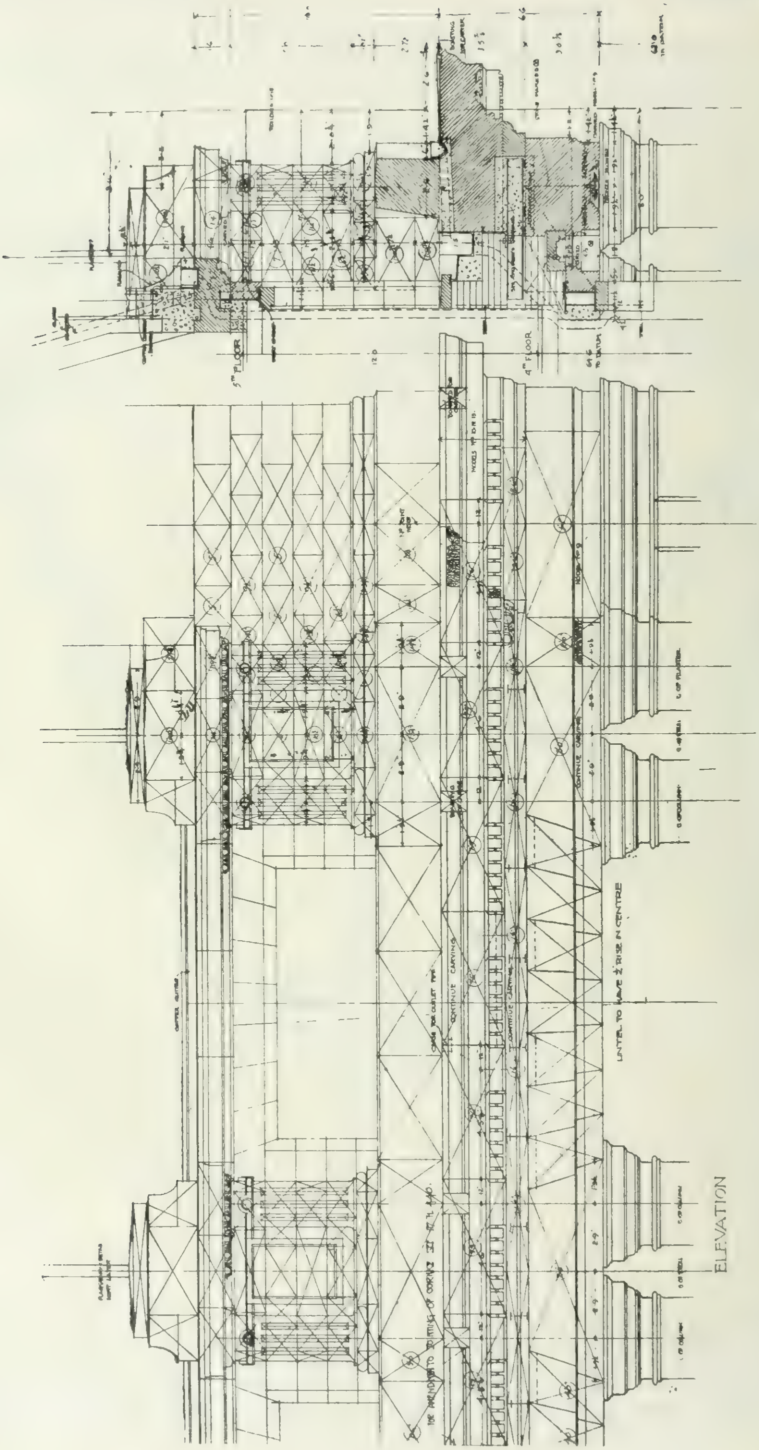


Fig. 3. **Entablature and Attic Storey.**
AUSTRALIA HOUSE.

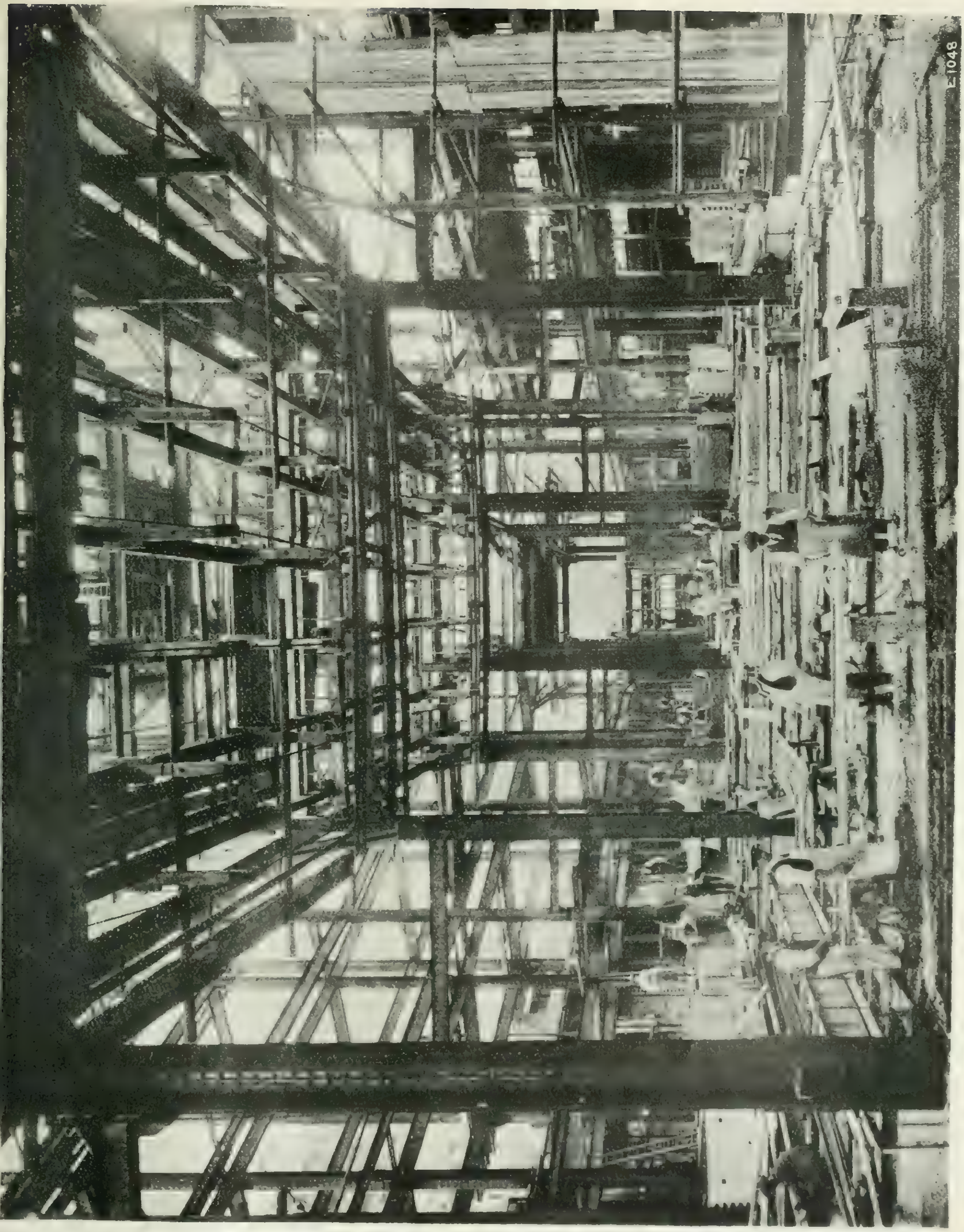


Fig. 4. Ground Floor during Erection
AUSTRALIA HOUSE.

CONSTRUCTION.

The building consists of basement, sub-basement, ground floor and six floors over. The basement floors are 11 ft. 6 in. and 10 ft. high respectively, and the ground floor is 30 ft. 6 in. to the first floor level, whilst the height from ground floor to roof is 99 ft. 6 in.

The main entrance leads to a vestibule having side entrances to both the Strand and Aldwych, and from this vestibule access is gained to a hall about 30 ft. square. The main staircase, planned on the two-way principle, is approached from this hall, and beyond is the Exhibition Hall, 88 ft. long by 64 ft. wide with semicircular recesses about 30 ft. wide on either side. Except for the entrances and a portion of the site occupied by the Victoria Government offices, the whole of the Strand and Aldwych frontages are reserved for commercial purposes.

The foundations of the building are 25 ft. below street level and consist of a concrete raft over the whole site. This raft is reinforced, where needed, to equally spread the superincumbent weights coming upon it, and over its upper surface is a layer of asphalte which is carried up to pavement level, so that the whole structure stands in a waterproof tank and is insulated from several underground streams that occur in the neighbourhood and which discharge into the Thames.

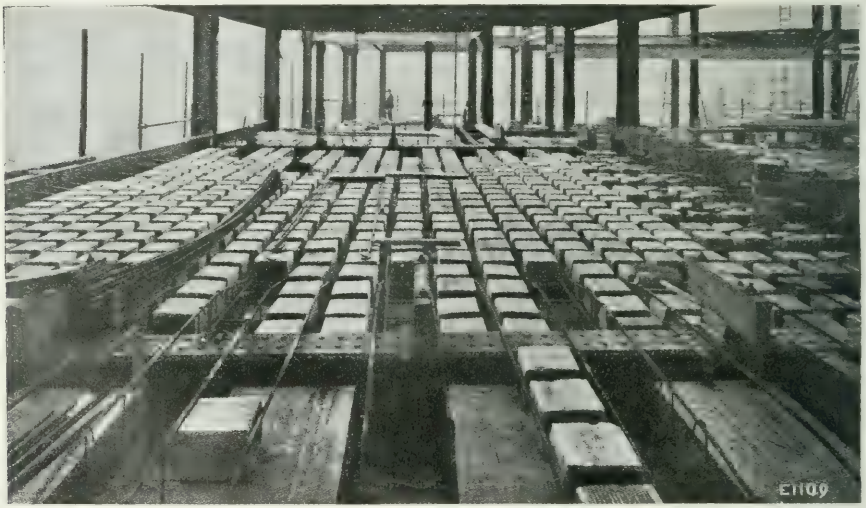


Fig. 5. View showing Floor Construction.
Australia House.

The building is fire-resisting throughout and is of steel-framed construction carried out to the requirements of the London County Council's General Powers Act, 1909, as to design and protection of steel and thickness of walls.

Owing to the plan of the site, exact " unit " planning of supports was impossible, but standardisation and uniformity was generally striven for in the arrangement of the steelwork. On the two main fronts the stancheons are placed at about 22 ft. centres, and 21 ft. from these is a second row, which thus divided the outer portion of the building into bays of about 22 ft. by 20 ft.

Within the Exhibition Hall only four stancheons are used, and these are placed within the massive piers which play so large a part in giving scale to this portion of the building.

After fixing, all steelwork was protected by a coating of cement wash, but during the delay consequent upon the war and labour troubles it was found that this covering was insufficient, and a covering of broken brick concrete was subsequently applied to the steelwork.

The basement and ground floors, which are designed for very heavy loads, are of reinforced concrete in small spans, but the upper floors are of much larger spans, some being of unbroken slabs of 32 ft. by 32 ft. constructed without any intermediate beams and having a thickness of 12 in. The majority of the bays, however, were about 22 ft. by 23 ft., with a thickness of 9½ in. All these floors were carried out on the "Cullum" fire-resisting principle, with perforated blocks, reinforced in both directions in their joints by steel rods so that all tension is taken by the steel and compression by the blocks and the concrete. The flats and sloping roof are of similar construction and the flats are finished with asphalte.

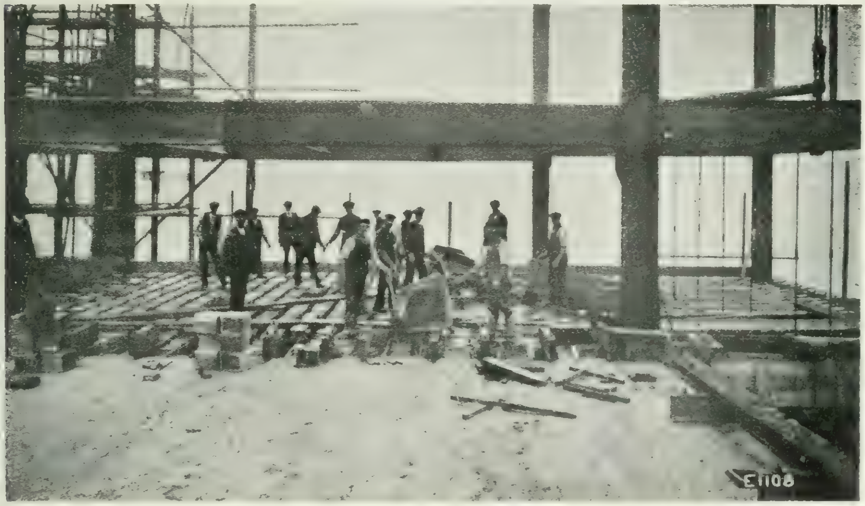
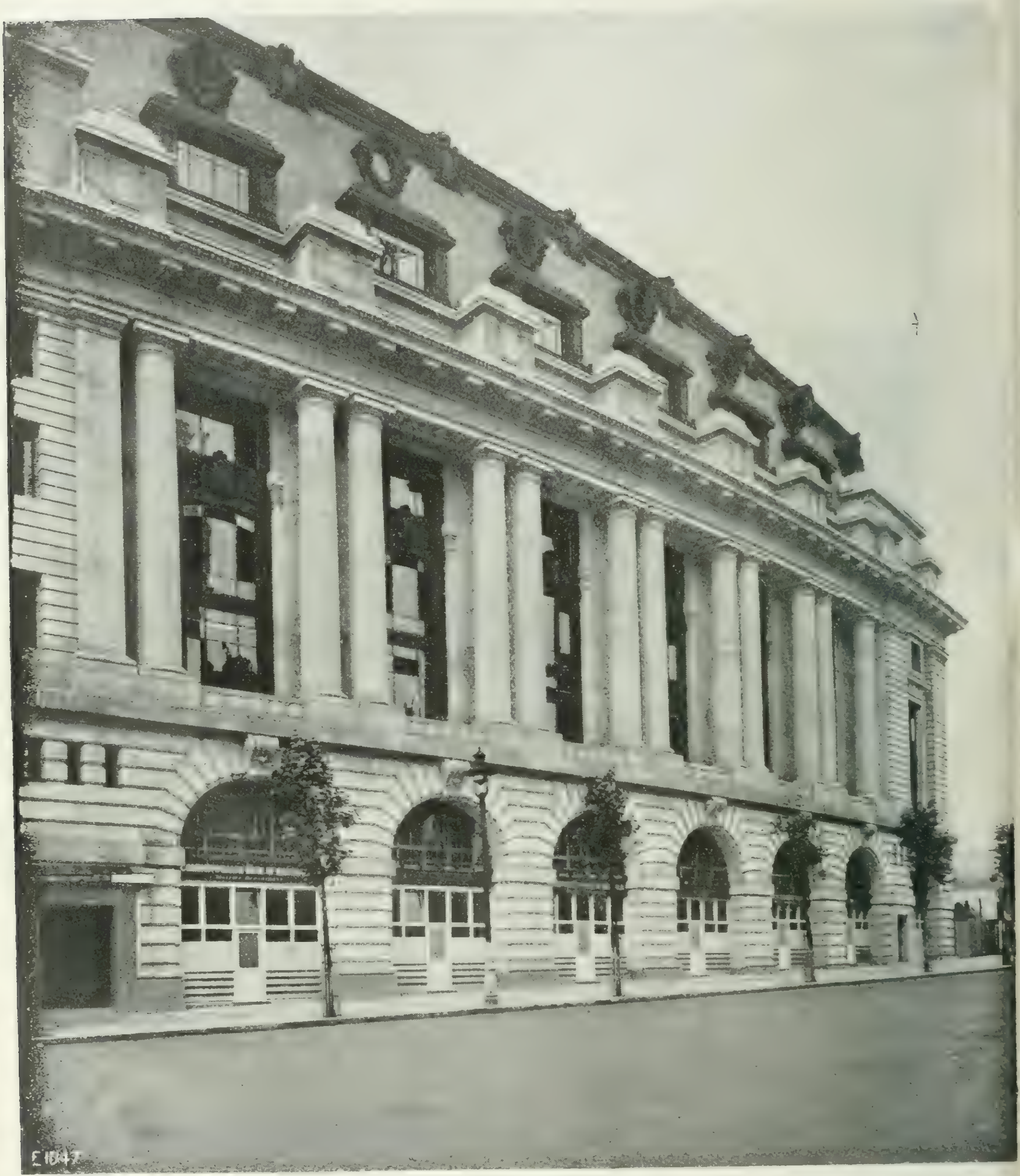


Fig. 6. View showing Floor Construction

AUSTRALIA HOUSE

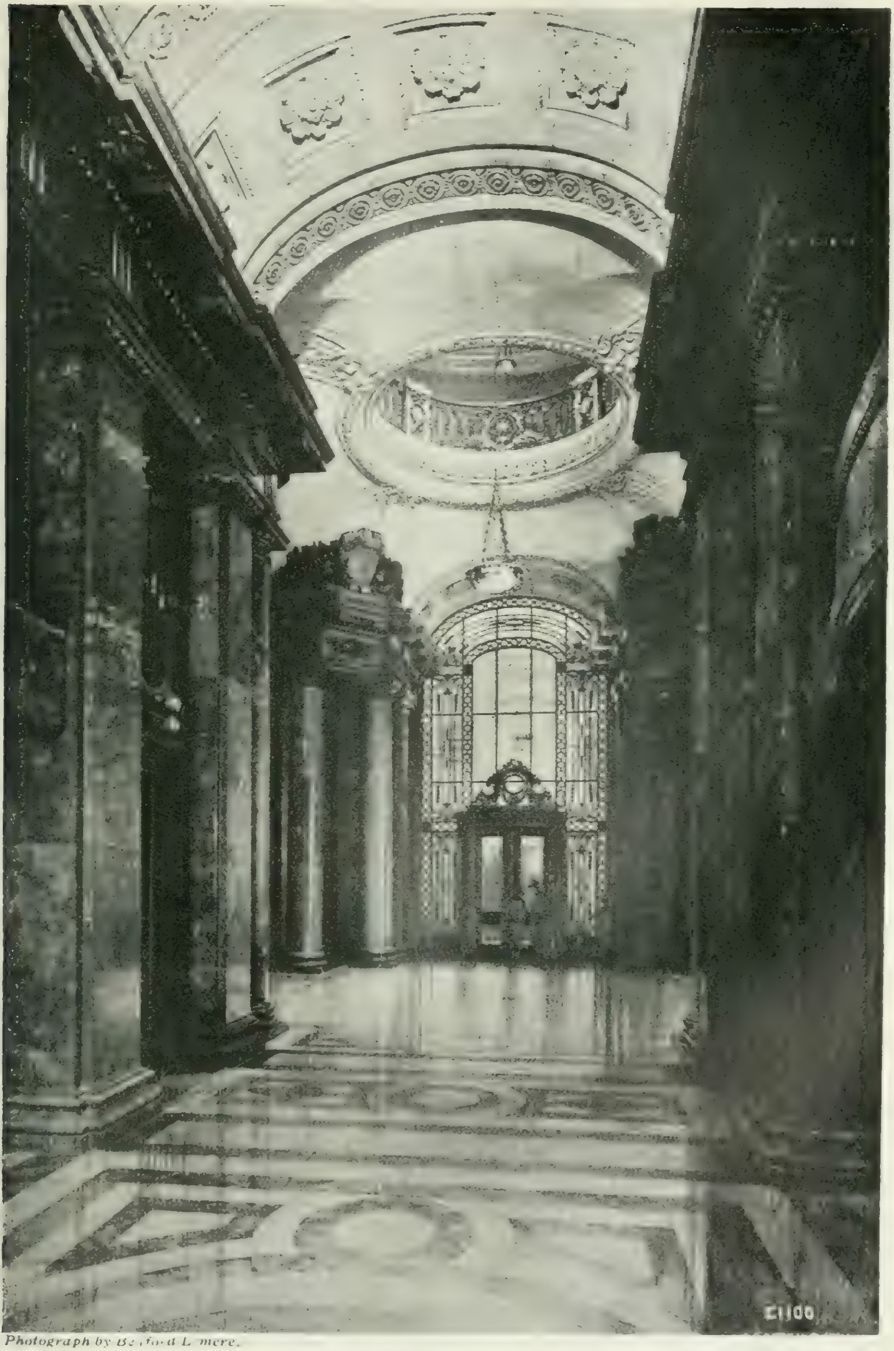
The external stonework was very carefully detailed, and the whole of the outer walls are constructed to be self-supporting. Lack of space prevents us from reproducing a series of details from ground level to roof, but the drawing of the entablature and attic storey (*Fig.* 3) is well worthy of study. The cornice has a depth of 3 ft. 5⅝ in. and a projection of about 3 ft. 8 in. The bed mould of cornice is of comparatively small stones, but the upper portion is of stones 2 ft. 6 in. in depth and 2 ft. 6 in. and 2 ft. 9 in. in elevation, each block being 7 ft. from nose of cornice to back.

The method of construction is clearly shown in the section reproduced, and it will be seen that the soffite is suspended from the lower flanges of steel joists. To prevent overturning the cornice is tailed down by bolts connected to small joists which run back to main wall and which are placed at about 2 ft. centres.



General View of Finished Building.

AUSTRALIA HOUSE.



Photograph by Bedford Lemere.

The Vestibule, looking East.
Australia House.

A tank with capacity of 30,000 gallons of water has been constructed on the roof of the building, and for the supply of water to the structure an artesian well was sunk at the time of commencement of the works.

A most interesting feature of the basement of the building is the triple treasury which has been built to suit the requirements of the Commonwealth Government officials. This treasury is of two floors, and is constructed to be entirely self-supporting. The total thicknesses of walls and roof are 12 in. and that of floor 9½ in. and the external dimensions are 19 ft. 9½ in. high, 17 ft. 10 in. wide and 11 ft. 1½ in. deep. The divisional floor between the upper and lower chambers is of ½-in. chequered steel plate on 6-in. R.S.J.'s, and to allow of access to the back of either door (in cases of emergency) a locked trap door is formed in it. The outer shell is of ½-in. tough Siemens steel and the inner shell of compound armour-plate ¾ in. thick, consisting of highly carbonised drill-resisting steel inserted between plates of tough Siemens steel, with a layer of copper ⅛ in. thick between same, thus making the inner shell ⅞ in. thick. The space between the inner and outer shell is filled with hard granite concrete in which are embedded twisted hard steel bars of flat section. These bars are arranged to run at right angles to each other at a pitch of about 12 in., thus giving square spaces between them of about 9½ in. The doors are of Chubb's anti-blowpipe crane-hinge doors, with clear opening of 3 ft. width and 7 ft. height, and are impervious to oxy-acetylene flame, fracture or drill.

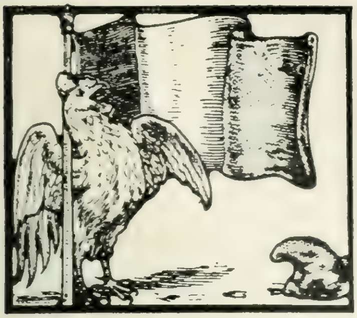
As an additional safeguard all the outer walls, floors and roof surrounding the triple treasury itself were constructed of reinforced concrete 1 ft. 10 in. thick, having embedded therein three separate cages of hard twisted steel bars.

Mr. Hamilton H. Turner, of 48, Broadway, Westminster, was the Quantity Surveyor for the building, and Mr. S. Bylander, who is now carrying out similar work for the Ottawa Government Building, was the Consulting Engineer, whilst Mr. W. Stark, to whose unceasing vigilance the fine quality of the work is greatly due, acted as Clerk of Works.

The General Contractors for the superstructure were Messrs. Dove Bros., of Islington, and for the foundations Messrs. Holloway Bros., of Westminster. The steelwork was carried out by Messrs. Redpath Brown, and it may be of interest to state that British steel was used throughout.

The contractors for the floors were Messrs. Horace W. Cullum and Co., and the Portland stone was supplied by the Bath and Portland Stone firms. Messrs. Chubb and Sons carried out the work for the triple treasury, and also supplied the other safe doors for the building. Among the others engaged may be mentioned Messrs. Ramsay and Co., London, for the great majority of the fine metal work and electric light fittings ; Messrs. Jenkins, of Torquay, for the marble work to Exhibition Hall ; Messrs. Wylie and Lockhead, Glasgow, for the woodwork of Library and first floor ; and Messrs. Turner Lord for the " Stuc " work to ceilings in Exhibition Hall and entrance.

The cost of purchase, including an arrangement as to the freehold of the site of the already existing Victoria building, amounted to £379,756, whilst the contracts for the building itself, including the estimated cost of material brought from Australia, were estimated in January, 1917, to involve an expenditure of over £450,000.



THE RAPID CALCULATION OF REINFORCED CONCRETE STRUCTURES.

BEAMS FOR FLOORS.

By N. DE TEDESCO,
Civil Engineer, Ecole Centrale, Paris.

The following article regarding the Calculation of Reinforced Concrete Structures concludes M. de Tedesco's treatise; the last article appeared in our January issue, page 26—ED.

Floors in reinforced concrete are composed of a slab incorporated with the rectangular beams supporting it. The calculation of these beams takes into account this slab in so far as the resistance to compression is concerned, but the theoretical width of this slab acting with each beam is reduced to the smallest of the following values: either the $\frac{3}{4}$ of the distance centre to centre l between the beams or the $\frac{1}{3}$ of the span L of these beams or 15 times the thickness ds of the slab.

If d is the effective height of the beam (including the thickness of the slab ds), namely, the distance between the axis of the bars in tension and the upper surface of the slab, we must take approximately for the lever arm or distance between the centres of tension and compression the following value:

$$a = d - \frac{5}{12}ds$$

d being, as mentioned, the effective height of the beam and ds the thickness of the slab.

We then find immediately the minimum value of A_t, or the section of steel required in square inches, by the equation

$$A_t = \frac{B}{at}$$

or preferably in succession:

$$F = \frac{B}{a} = \text{the effort of tension or compression and } A_t = \frac{F}{t} = \frac{F}{16000}$$

If we call f the distance between the upper surface of the slab and the point of application of the resultant of the compressive forces, the exact value of f is:

$$f = \frac{3n - 2ds}{2n - ds} \times \frac{ds}{3}$$

and not the approximate value $\frac{5}{12}ds$, suggested above.

The distance n between the neutral axis and the upper surface of the slab is unknown. This distance varies between two limits, viz.: $n = ds$, when this neutral axis coincides with the under surface of the slab. We then have:

$$f = \frac{3ds - 2ds}{2ds - ds} \times \frac{ds}{3} = \frac{ds}{3}$$

n, very great as compared to ds, in which case we may neglect $2ds$ beside $3n$ and ds beside $2n$, hence:

$$f=\frac{3n}{2n}\times\frac{ds}{3}=\frac{ds}{2}$$

Between these two limits:

$$f=\frac{ds}{2} \text{ and } f=\frac{ds}{3}$$

If we take the average $\frac{5}{12}ds$, there is only an actual error amounting to $\frac{ds}{12}$, which is a very small one of $\frac{1}{3}$ in., in the case of $ds=4$ in. and a relative error, still less important, in the length of the lever arm $a=d-f$, seeing that d is always large as compared with f.

The following examples will show the simplicity of this method of calculation.

I.—*Find the reinforcement in tension of beams* 8 *in. wide and* 20 *in. deep, spaced* 6 *ft. centre to centre, and having a superload of* 2 *cwt. per sq. ft. on a span of* 20 *ft. The thickness of the slab is* 4 *in.*

Loads per foot:

$$\begin{array}{lrl} \text{Slab,} & 4\times13 = & 52 \text{ lb.} \\ \text{Superload,} & 2\times112= & 224 \text{ ,,} \\ \hline \text{Per foot run} & & 276 \text{ ,,} \end{array}$$

$$\begin{array}{lrl} \text{Weight on the beam,} & 276\times6 & =1656 \text{ lb.} \\ \text{Dead weight of beam,} & 8\times20\times\frac{156}{12\times12} & = 174 \text{ ,,} \\ \hline \text{Total loads} & & 1830 \text{ lb. per foot run.} \end{array}$$

Bending moment:

$$B=\frac{1830\times20^2\times12}{8}=1098000$$

We then have: $d=20$ in. $+4$ in. (less the cover of the bars in tension from below their axis, which we can estimate at 2 in.).

Hence:

$$d=20+4-2=22$$

$$f=\frac{5}{12}\times4=1{\cdot}67$$

$$a=d-f=22-1{\cdot}67=20{\cdot}33$$

$$F=\frac{B}{a}=\frac{1098000}{20{\cdot}33}=54009$$

$$A_t=\frac{54009}{16000}=\frac{F}{t}=3{\cdot}38$$

In order to realise this section we can, for instance, provide six round bars of $\frac{7}{8}$ in. $=3{\cdot}606$, arranged as in Fig. 1.

It will be noticed that until now we have not considered the working stress of the concrete in compression which must not exceed 600 lb. per sq. in.

In general, if the spacing of the beams is not too small and if the depth of the beam has been amply provided for, which is an obvious measure to economise the steel, this working stress is far from being reached. Anyhow, in case there is any doubt on this point, there is a rapid means of verification, viz.: The distance l between the beams being 6 ft., the span L 25 ft., and the thickness of the slab 4 in., we have said that we must take for the effective width b of the slab the smallest of the following quantities :

$$\cdot 75 \times 6 \times 12 = 54\ ;\quad \frac{20 \times 12}{3} = 80\ ;\quad 15 \times 4 = 60$$

We must therefore take $b = 54$ in. ; we then get a total sectional area of concrete equal to $54 \times 4 = 216$. The average working stress ρ of the concrete is therefore :

$$\frac{F}{216} = \frac{54009}{216} = 250$$

The maximum working stress is $c = \dfrac{\rho}{1 - \dfrac{ds}{2n}}$

Unfortunately we do not know n beforehand, but if we take the most unfavourable case, viz., $n = ds$, we have $c = 2\rho$. The result is that we obtain entire security when we get :

$$\rho < \frac{c}{2} \text{ or } < 300 \text{ lbs.}$$

Such is the case of this example.

Verification.

If we wish to verify the above we must apply the general equation which gives us the value of n.

$$(b - b')ds\left(n - \frac{ds}{2}\right) + \frac{b'n^2}{2} - mA_t(d - n) = 0$$

$$b = 54,\ b' = 8,\ ds = 4,\ m = 15,\ A_t = 3 \cdot 38,\ mA_t = 50 \cdot 7,\ d = 22$$

Therefore :

$$(54 - 8) \times 4 \times \left(n - \frac{4}{2}\right) + \frac{8 \times n^2}{2} - 50 \cdot 7(22 - n) = 0$$

$$184\ (n - 2) + 4n^2 - 50 \cdot 7\ (22 - n) = 0$$

$$n^2 + 58 \cdot 675n - 370 \cdot 85 = 0$$

$$n = 35 \cdot 098 - 29 \cdot 3375 = 5 \cdot 7555$$

Knowing n we can more accurately calculate c :

$$c = \frac{\rho}{1 - \dfrac{ds}{22}} = \frac{250}{1 - \dfrac{4}{11 \cdot 511}} = 384$$

Similarly we can know more accurately :

$$f = \frac{3n - 2ds}{2n - ds} \times \frac{ds}{3} = \frac{3 \times 5 \cdot 7555 - 2 \times 4}{2 \times 5 \cdot 7555 - 1 \times 4} \times \frac{4}{3} = 1 \cdot 645$$

The rapid method had given us $f = 1 \cdot 67$.

Finally, if we wish to complete the verification, we must calculate the moment of inertia by the general formula :

$$I = (b - b')\frac{n^3 - (n - ds)^3}{3} + b' \times \frac{n^3}{3} + mA_t(d - n)^2$$

namely, for :

$$b = 54,\ b' = 8,\ b - b' = 46,\ n = 5 \cdot 7555,\ n^3 = 190 \cdot 65,\ (n - ds)^3 = 1 \cdot 7555^3 = 5 \cdot 41,$$

$$mA_t = 15 \times 3 \cdot 38 = 50 \cdot 7,\ d - n = 22 - 5 \cdot 7555 = 16 \cdot 2445$$

$$I = 46 \times \frac{190{\cdot}65 - 5{\cdot}41}{3} + 8 \times \frac{190{\cdot}65}{3} + 50{\cdot}7 \times 16{\cdot}2445^2$$

$$I = 2840{\cdot}50 + 508{\cdot}40 + 13383{\cdot}78 = 16732{\cdot}68$$

$$K = \frac{B}{I} = \frac{1098000}{16732{\cdot}68} = 65{\cdot}62$$

$C = Kn = 65{\cdot}62 \times 5{\cdot}7555 = 377{\cdot}67$ instead of 383

$t = K \times (d - n) \times m = 65{\cdot}62 \times 16{\cdot}2445 \times 15 = 15989{\cdot}46$ instead of 16000.

II.—*Find the reinforcement in tension and, if necessary, the reinforcement in compression for beams 6 in. wide and 16 in. deep, spaced 4 ft. apart and having a superload of 2 cwt. on a span of 25 ft., the thickness of the slab being 3 in.*

Load per ft. :

Slab $3 \times 13 =$	39
Superload $2 \times 112 =$	224
	263

Load on the beam per ft. run $263 \times 4 = 1052$

Dead weight of beam $6 \times 16 \times \frac{156}{12 \times 12} = 104$

$$1156$$

$$B = \frac{1156 \times 25^2 \times 12}{8} = 1083750$$

We have $d = 16 + 3$ (less the cover of the bars in tension below their axis, which we will assume equal to 1·50 in.)

$$d = 16 + 3 - 1{\cdot}50 = 17{\cdot}50$$

$$f = \frac{5}{12} \times ds = \frac{5}{12} \times 3 = 1{\cdot}25$$

$$a = d - f = 17{\cdot}50 - 1{\cdot}25 = 16{\cdot}25$$

$$F = \frac{B}{a} = \frac{1083750}{16{\cdot}25} = 66692{\cdot}3$$

$$A_t = \frac{F}{t} = \frac{66692{\cdot}3}{16000} = 4{\cdot}1683$$

If we now examine what happens in compression, we find that of the three quantities

$${\cdot}75 \times 4 \times 12 = 36\ ; \quad \frac{25 \times 12}{3} = 100\ ; \quad 15 \times 3 = 45$$

the smallest is $b = 36$

Which gives us an effective section of concrete of $3 \times 36 = 108$.

$$p = \frac{66692{\cdot}3}{108} = 617{\cdot}52 > \frac{600}{2}$$

We can therefore see that the maximum stress c will be greater than 600 and that it will become necessary to provide bars in compression.

Evidently, in this case, the value of n is known beforehand and equal to ${\cdot}36d = {\cdot}36 \times 17{\cdot}50 = 6{\cdot}3$, assuming of course that we take

$$m = 15\ ; \quad c = 600\ ; \quad t = 16000$$

From which we obtain more exactly :

$$f = \frac{3n - 2ds}{2n - ds} \times \frac{ds}{3} = \frac{3 \times 6{\cdot}3 - 2 \times 3}{2 \times 6{\cdot}3 - 1 \times 3} \times \frac{3}{3} = 1{\cdot}34.$$

We had previously found approximately 1·25.

$$a=d-f=17{\cdot}50-1{\cdot}34=16{\cdot}16$$

$$A_t=\frac{66692{\cdot}3}{16{\cdot}16}=4{\cdot}13$$

The value of A_c will be given by the equation :

$$A_c=\frac{\dfrac{Bn}{d-f}-cbds\left(\dfrac{2n-ds}{2}\right)}{mc\,(n-f)}$$

$$A_c=\frac{\dfrac{1083750\times6{\cdot}3}{16{\cdot}16}-600\times36\times3\left(\dfrac{2\times6{\cdot}30-3}{2}\right)}{15\times600(6{\cdot}30-1{\cdot}34)}$$

$$A_c=\frac{422502-311048}{44640}=2{\cdot}497$$

Verification.

We can verify the value which we have assumed for A_c by the general equation giving the moment of inertia and taking into account the value which we have found for A_c. Hence, $mA_c=15\times2{\cdot}497=37{\cdot}50$. $A_t=4{\cdot}13$; $mA_t=15\times413=61{\cdot}95$. We notice that the proposed value of A_c is on the assumption that the axis of the bars in compression is situated at a distance f calculated as mentioned above; of course, if we can place the axis higher up, we can diminish slightly the working stress.

The general equation takes this form :

$$I=(b-b^1)\frac{n^3-(n-ds)^3}{3}+b'\frac{n^3}{3}+mA_c(n-f)^2+mA_t(d-n)^2$$

namely, for :

$$b=36\ ;\ b'=6\ ;\ b-b'=36-6=30\ ;\ n=6{\cdot}3\ ;\ n-ds=6{\cdot}3-3=3{\cdot}3$$

$$mA_c=37{\cdot}50\ ;\ n-f=6{\cdot}3-1{\cdot}34=4{\cdot}96\ ;\ mA_t=61{\cdot}95\ ;\ d-n=17{\cdot}5-6{\cdot}3=11{\cdot}20$$

$$I=\frac{30}{3}(6{\cdot}30^3-3{\cdot}30^3)+\frac{6\times\overline{6{\cdot}30}^3}{3}+37{\cdot}5\times4{\cdot}96^2+61{\cdot}95\times\overline{11{\cdot}20}^2$$

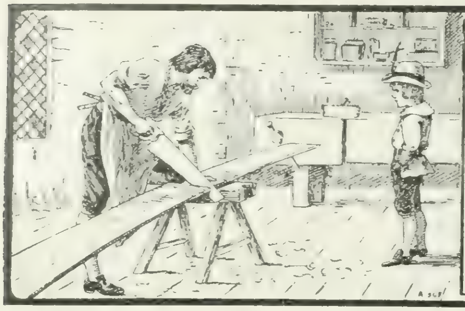
$$I=2140{\cdot}60+500+922{\cdot}50+7771{\cdot}10=11334{\cdot}20$$

$$K=\frac{B}{I}=\frac{1083750}{11334{\cdot}20}=95{\cdot}62$$

$$c=Kn=95{\cdot}62\times6{\cdot}3=602{\cdot}40$$

$$t=K\times(d-n)\times m=95{\cdot}62\times11{\cdot}20\times15=16064.$$

The small differences amounting to 3 per cent. are the result of decimals which have been neglected.



THE HOUSING QUESTION.

TEN HOUSES OF FIELD AND PRE-CAST CONCRETE.

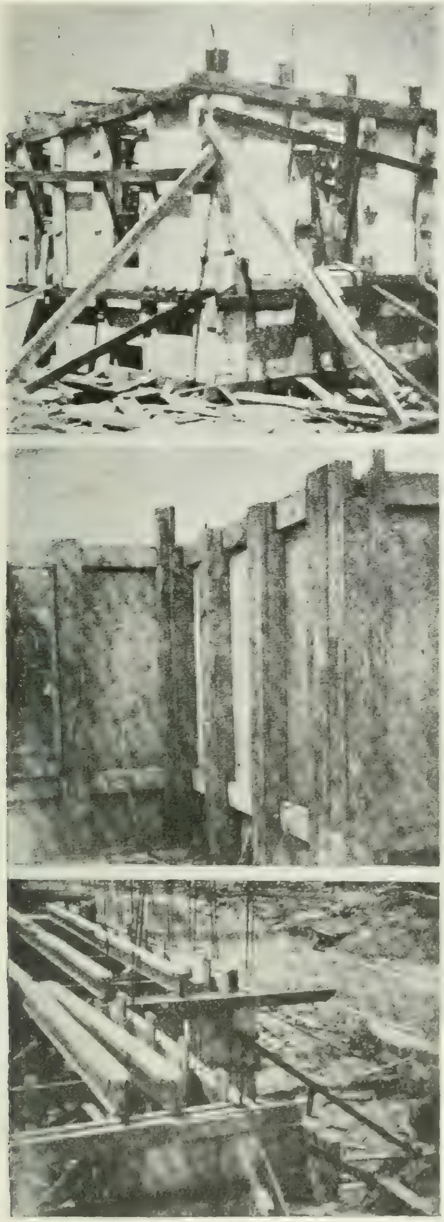
In a recent issue of our contemporary "Concrete," U.S.A., there appeared an interesting article regarding the erection of concrete houses of field and pre-cast units. The article is descriptive of the special system employed, and contains a number of illustrations, some of which we reproduce herewith, together with the text of the article. In dealing with cost of erection, it must be remembered that the author's figures are based on prices and practices ruling in America.—ED.

Ten six-room dwellings are being completed at Lansford, Pa., for the Lehigh Coal & Navigation Company, by the Simpsoncraft system of concrete construction. Work is being done on a lump contract amounting to $30,000—$3,000 per house.

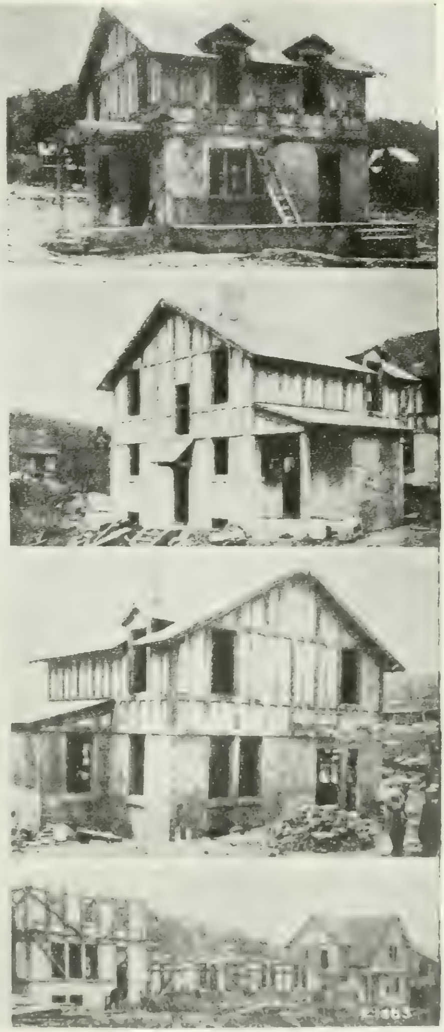
The houses in various stages of construction are shown in the accompanying illustrations. There are eight separate structures, two of them double houses.

The system here described involves the use of pre-cast reinforced units, most of them light and readily handled, set up on a monolithic foundation wall and tied together by other reinforced structural members which are cast in place. An inspection of the ten-house job at Lansford, which has not progressed rapidly, suggests that the system is extremely elastic in design and far more simple in actual fabrication and erection than might appear from the inventor's details. Its successful application to extensive housing enterprises (it would not, it seems, be economical for single dwellings or extremely small groups) depends, like a good many other developments, which have gone slowly in the concrete field, upon the thorough training of two or three men in the details of the system and the thorough organisation of a crew. A good carpenter and a good cement finisher under a competent superintendent, with an organised crew of average intelligence should be able to standardise operations in pre-casting, erecting and field pouring and finishing so as to give a good construction at low cost. Most of the work done with the system has been on a small scale and insufficient in extent to develop a suitable organisation for economical results. The work on the ten houses at Lansford offered an opportunity, and while the contract is being put through at a price of $3,000 per house, the contractor, due perhaps to lack of organisation under trying labour conditions has not taken the fullest advantage of an opportunity.

Walls and floors are constructed with thin pre-cast slabs in convenient dimensions poured and finished on pallet forms in a shop on the job. These are reinforced with a welded wire fabric, which projects at the edges for tying up with the field cast structural members. They are slid off the pallets and stood on end twenty-four hours after finishing. The exposed surface of wall slabs may be finished as desired—trowelled, floated, brushed or scratched for

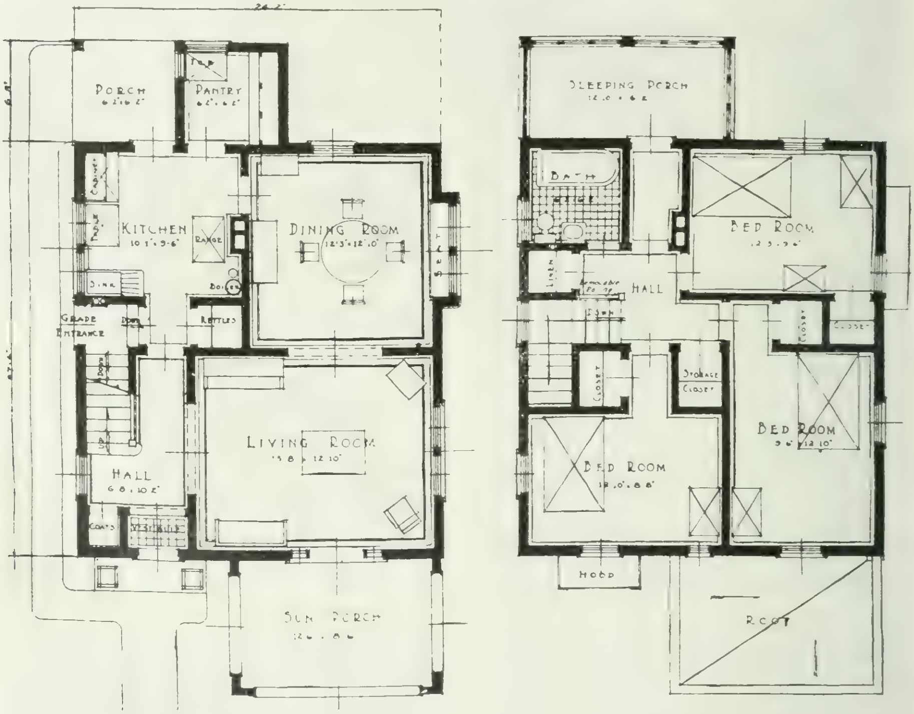


Figs. 1. 2. 3. Views showing method of construction.



Figs. 4, 5, 6, 7. Illustrations of a typical house nearly complete. Bottom illustration gives a general view of a group.

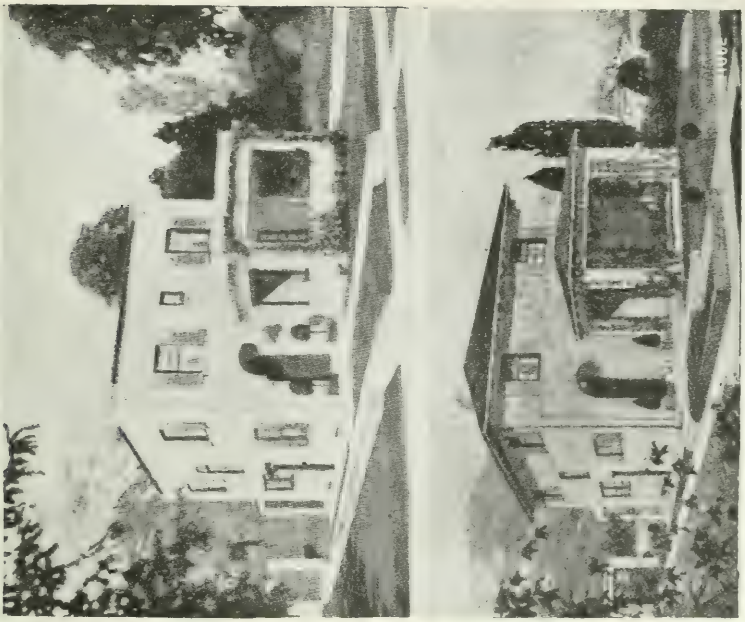
stucco application. Horizontal belt courses and sills, suitably reinforced and having projecting rods to tie into field cast members, are also shop-made in moulds providing slots which admit the thin wall slabs. Combination risers and treads for stairs are also shop-made to be tied together by field-cast strings. Balustrades are either shop cast, or field cast with strings, as desired. I-beams for floors are the heaviest shop cast members. For the first floor above the monolithic foundation floor I-beams are spaced on horses set on shims at floor height. For a panelled ceiling pre-cast slabs are placed so as to rest on the upper edges of the lower I-beam flanges. For flush, plastered ceilings, wire loops in the bottom of the beams support metal fabric. For the floor, the thin pre-cast slabs rest on the I-beams, and the joints covered by a concrete floor 1 in. thick, finished in place. For a wood floor finish wire ties cast into the floor slabs permit securing the sleepers to which the finish is nailed.



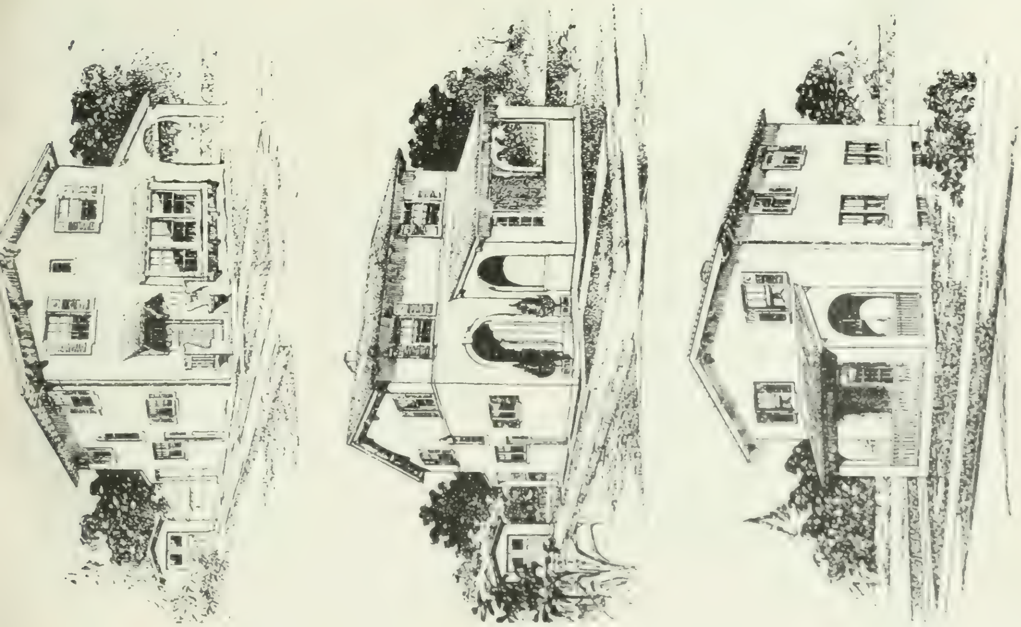
Figs. 8 and 9. Floor Plans for a six-room house similar to those erected at Lansford. For this plan five different treatments are suggested (see Figs. 10, 11, 12, 13, 14).

Walls are built up with a horizontal, pre-cast, slotted belt course at storey heights, or at other levels to suit design, with thin slabs between, the actual structure of the work depending on field-cast studs or small pilasters, poured in place, which join the slabs, belt courses and studs in a stiff construction.

These vertical members may be cast with an exterior projection to give a panelled effect or flush outside where stucco is to be applied on a plain field. The interior projection of the stud provides the tubular wall, furring and lathing being applied inside. These field-cast studs, in which the reinforcing rods are continuous for the height of the house above the first floor level, support the



Figs. 10, 11, 12, 13, 14. Showing five architectural treatments of floor plans shown in Figs. 8 and 9, and erected on the system described in present article.



beams of the upper floors, the projecting rods of the beams locking into the vertical rods of studs when the field casting is done.

In actual erection slabs are set up at wall corners and horizontal strings thoroughly braced for alignment. If the walls are flush outside, a plank covers the vertical joint between slabs and provides the outside form of the stud, while three form boards with rounded fillets at corners provide the interior form. The two sides are wired through, twisted and wedged. If panelled outside, a portion of the stud thickness is provided outside by a shallow channel mould.

The system is architecturally elastic because the vertical studs may be spaced as required to meet structural demands and be hid in the finished work, while in panelled effects, as in the upper storeys of the houses under construction at Lansford, vertical ribs may be merely false studs cast in the shop with such spacing as is desired.

MEMORANDUM.

The Proposed 300,000 Cottages.—Writing on this subject to the *Architect*, Mr. John Murray says :—

As there still appears to be much uncertainty about this problem, may I be allowed to submit the following points for consideration of all interested in connection with this important question, the best solution of which may necessitate the adoption of an entirely new system ?

1. A large number of so-called temporary buildings with thin concrete walls have been erected during the war and used for dwellings satisfactorily. They will last for a few years, and they are cheap and sanitary.

2. The Local Government Board of Scotland has decided to build for housing somewhat similar cheap concrete buildings that are calculated to be of a more permanent nature.

3. If so-called temporary cottages were built for all the housing required immediately after the war, they could be erected very rapidly, would probably last about ten years, be cheap, sufficient for all necessary purposes, and release at an early date much labour for other essential trade developments for which speed is the very essence.

4. The great electricity scheme recommended by the Board of Trade Committee a few months ago, and which is proceeding, will probably provide a huge amount of electric power throughout the country within a few years.

5. About ten years hence a vast amount of electricity will doubtless be available throughout the country for domestic heating and lighting, probably at a cost of only a fraction of a penny per unit. At that time money will probably be much cheaper, and concrete or other cottages heated and lighted by electricity could be built at an economical cost, and calculated to last for, say, about fifty years or more.

6. Having regard to the vast and rapid development of all branches of science that will assuredly occur during the next fifty years, there does not appear to be any sufficient reason why it should be necessary or expedient to build cottages of a more substantial or costly nature than are calculated to live for more than about fifty years.

7. If these several relative facts have not yet been fully considered in connection with this problem, it would appear to be very desirable for it to be done now before the country is committed to a programme that may not prove to be the most sound, either scientifically or economically.

Panorama of Back Slipways for Concrete Ships, Poole Harbour.

CONCRETE SHIPBUILDING IN THE SOUTH OF ENGLAND

In the present article we give illustrations and short particulars of some recent concrete shipbuilding developments in this country.

Poole Shipyard.—In a recent number we made brief reference to the launching of a 1,000-ton barge which had been built at this yard. A second barge has since been launched, and we are now able to present a number of illustrations of these concrete ships.

The shipyard where these boats are being constructed occupies a total area of nearly 250 acres with a water frontage of $1\frac{1}{4}$ miles in the harbour. Work on the site was commenced in December 1917.

The slipways were specially designed to suit the construction of concrete ships by Mr. E. O. Williams, B.Sc., A.M.Inst.C.E., Chief Engineer of the shipyard, Mr. Anthony G. Lyster, M.Inst.C.E., being the Consulting Engineer.

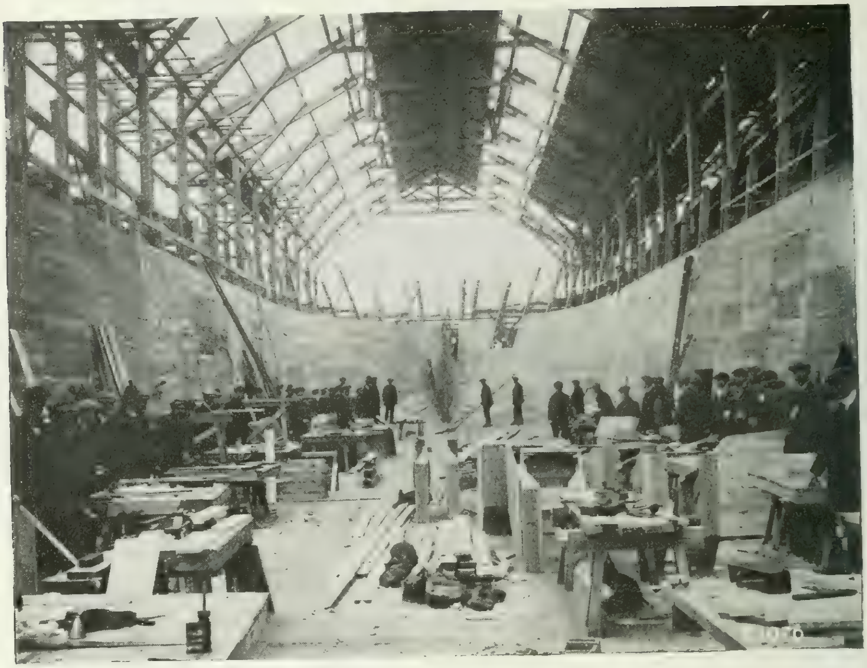
The barges and tugs shown in the accompanying illustrations were also designed and are being built under the supervision of Mr. E. O. Williams.

Two special features of the yard are :—

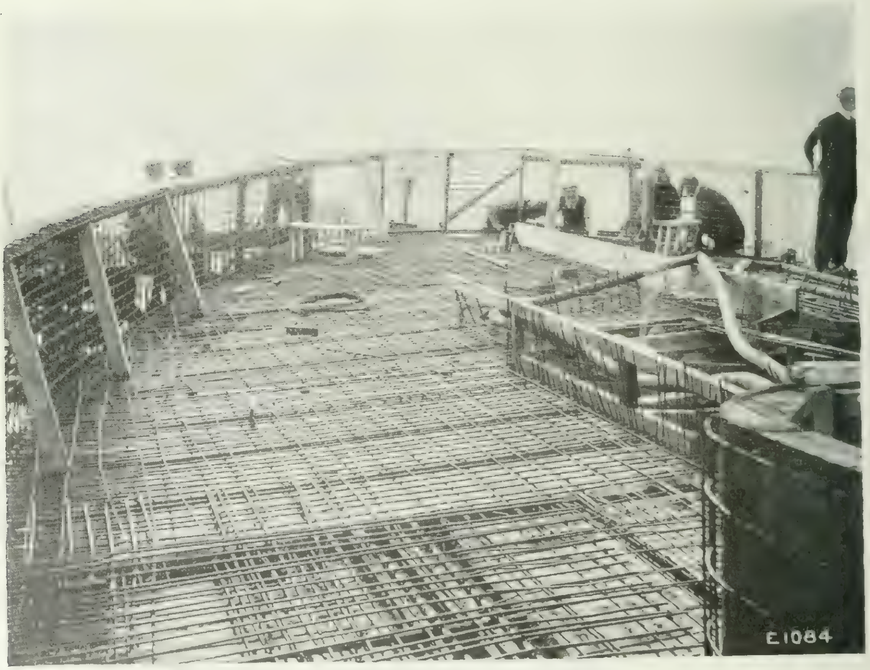
(1) Permanent crosswalls or keel blocks, on which the bottom shuttering of a vessel can rest, and so arranged that the whole of the shuttering of the vessel is removable without being destroyed.

(2) Permanent gantries between the slipways, and connected at their upper ends by a cross-gantry which connects a unit of 10 slipways together. The upper gangway of the gantry is practically at the level of the decks of the vessels, and on this upper gangway all the concrete is conveyed from the mixer to the sides of the ships.

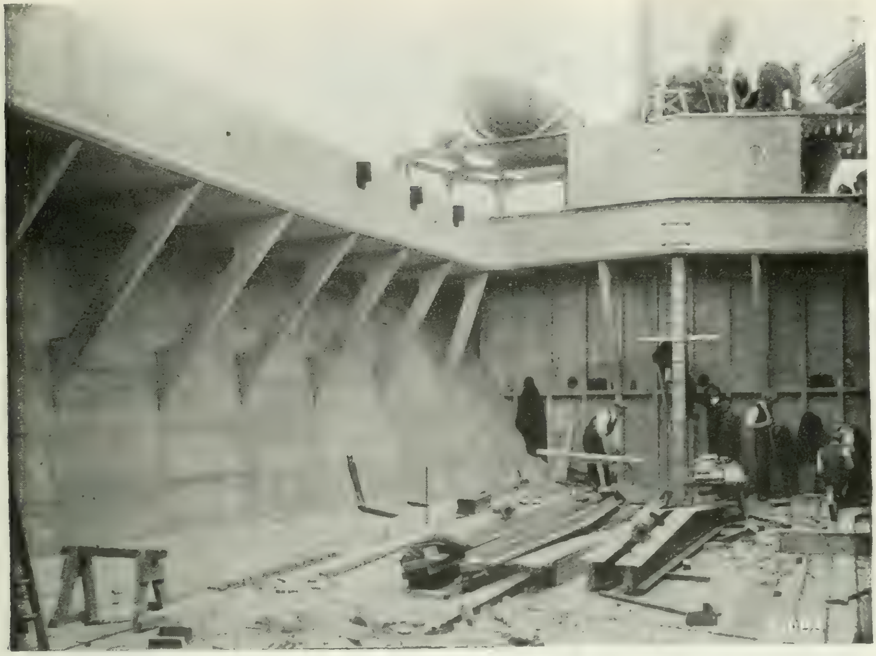
The barges are reinforced by small bars arranged horizontally and vertically to form a rectangular network. Larger bars, constituting the tension and compression reinforcement in beams and struts, are connected by web members



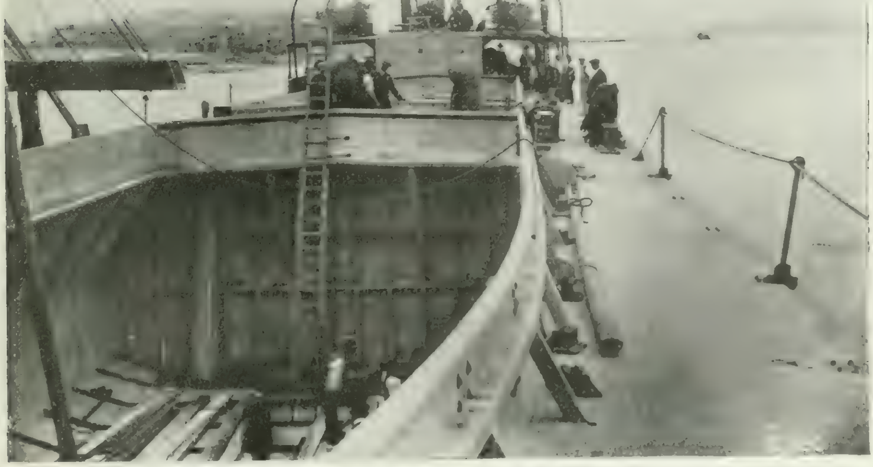
Interior of 1,000-ton Barge, showing external shuttering or falsework.



Deck and Bulwark Reinforcement– aft end.
1,000-ton Barge at Poole.

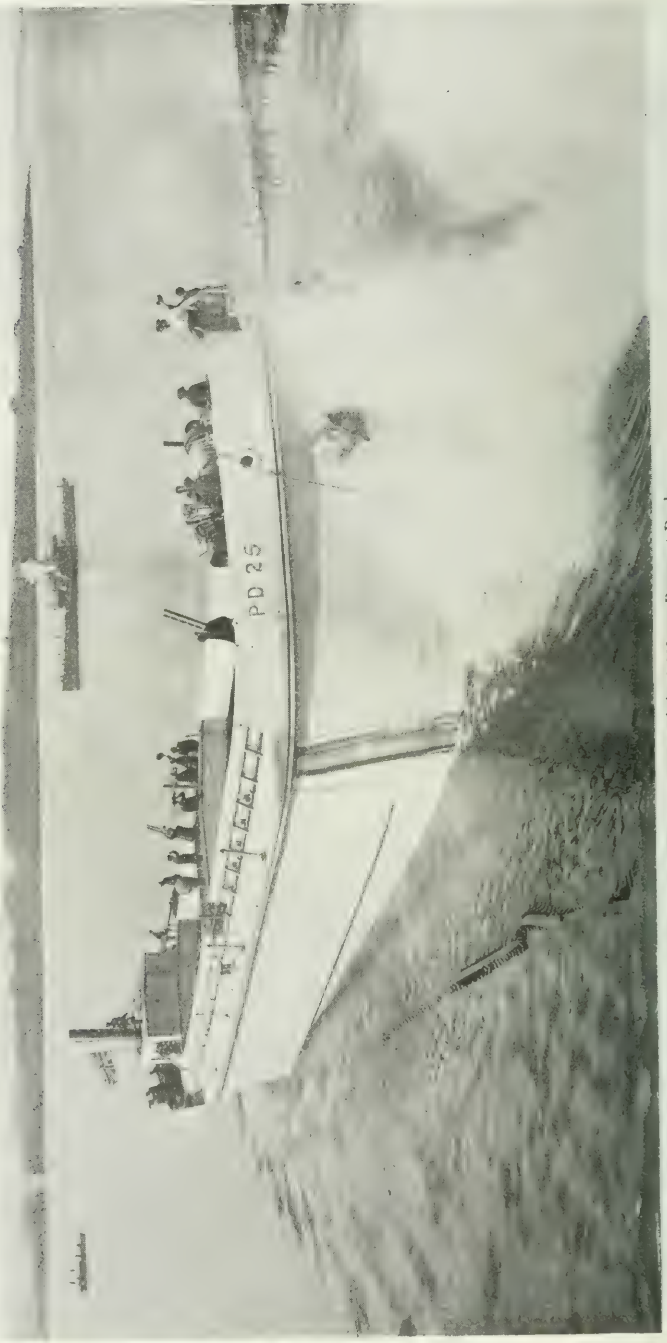


Interior of Hold.



Deck View, showing accommodation house aft

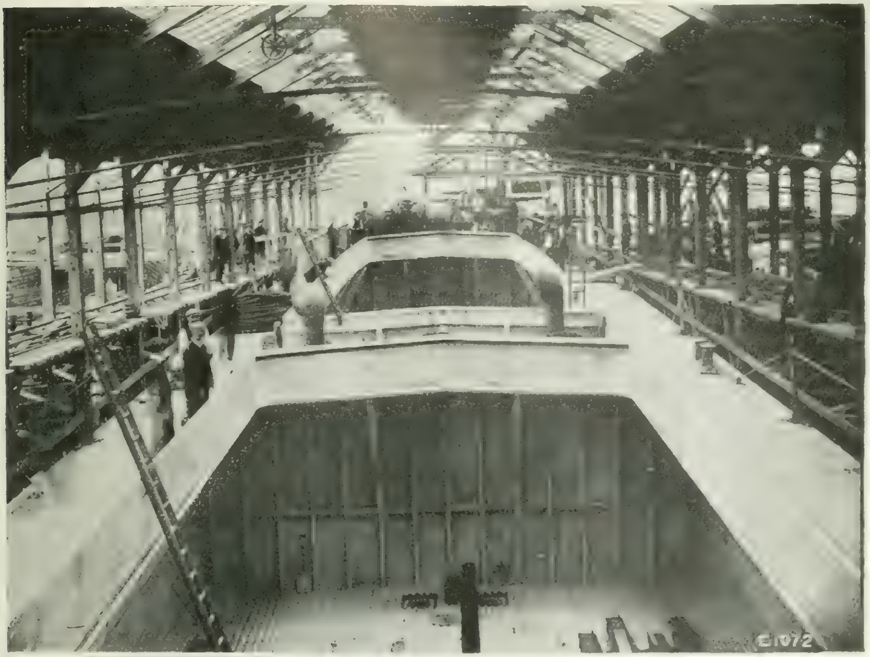
1,000-ton Barge at Poole.



The launching of the 1,000-ton Barge at Poole.

CONCRETE SHIPBUILDING IN THE SOUTH OF ENGLAND.

in the form of ties, which are electrically welded in place. The vessels have double bottoms and sides, enclosing the transverse frames. The upper deck is designed on the cantilever principle, and receives support at the hatchways from a series of diagonal struts projecting from the sides and branched out from the vertical ribs, the three structural elements at each rib constituting a triangular frame of great rigidity. The double bottom is formed by two 3 in. slabs about 3 ft. apart, connected and stiffened by longitudinal and transverse ribs. The latter are continued up the sides of the vessel between the two 3 in. walls of the hull, the spaces between the ribs being occupied by hollow cores of concrete reinforced by wire netting. These cores are made of 24 in. lengths, and form the inner part of the moulds for the concrete of the walls and ribs, thereby saving labour and material and helping to consolidate the construction.

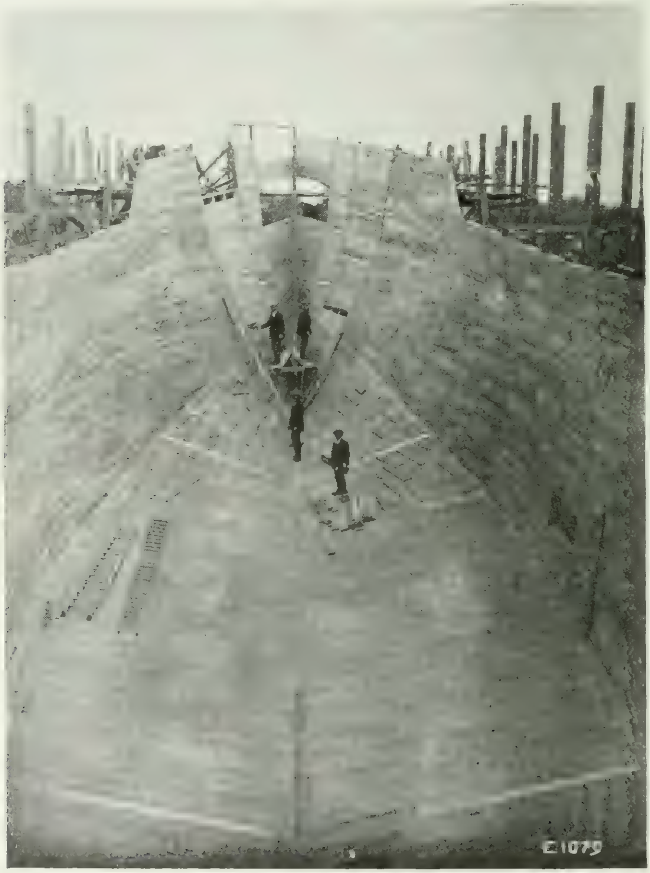


Complete Barge in Slipway day before launching.
1,000-TON BARGE AT POOLE.

These barges have two holds and three transverse watertight bulkheads, accommodation for the captain, crew, machinery and stores being provided at the bow and stern. Those designed for carrying oil in bulk are divided to form two oil tanks by cellular longitudinal and transverse bulkheads.

A number of small tugs are also under construction and an illustration of these is also given.

In the vessel designed by Capt. J. H. Waller, D.S.O., R.E., and now also under construction at the Poole Shipyard, the hull is formed of pre-cast reinforced concrete plates, from which the ends of the reinforcing bars project. When the plates are put in position in the vessel the bars are interwoven and locked around a pair of bars placed in the space left between adjacent plates, and form part of the reinforcement of the transverse frames extending along the bottom, up the sides, and under the deck of the vessel. After the bottom and side plates have been laid and secured in position, the reinforcement of the frames is assembled, and the main longitudinal reinforcement 2 in. diameter bars, for withstanding hogging and sagging stresses, is fixed in place. After the reinforcement for the bulkheads and the centre keelson has been assembled and secured the concrete is complete. The decking hatchway combings and bulkheads are constructed on the same principle as the hull. The plates are moulded on the flat, one on top of another, with a coat of whitewash between each pair. The correct disposition of the reinforcement is assured by edge moulds, and by trowelling the surface while the concrete is still wet a very smooth finish and a high degree of impermeability are obtained. The object of the Waller system is to reduce the amount of shuttering required, to lessen the labour, and to shorten the time occupied in construction.



The Stem of an 800-h.p. Tug under construction at Poole.
View shows external shuttering.

TESTS OF BLAST FURNACE SLAG AS THE COARSE AGGREGATE IN CONCRETE.

By P. J. FREEMAN.*

Considerable attention is being devoted to the value and advantages of blast furnace slag as an aggregate in concrete, and we therefore publish the following Paper, dealing with some tests carried out, which was read at the recent meeting of the American Society for Testing Materials —ED.

Blast furnace slag has been used as the coarse aggregate in concrete for a number of years, and numerous laboratory tests have been made during that time ; but these tests were conducted by different individuals, and with different cements and fine aggregates, and it is difficult to make direct comparisons of the results obtained.

In order to secure comparative data, a series of tests was planned in which the materials would be collected from various localities at one laboratory, and where all specimens would be made by the same operators, under uniform conditions.

The whole 5-year series of tests will not be completed until December, 1921, and this paper only includes the data obtained during the first year.

PURPOSE OF TESTS.

The purpose of this series of tests was to furnish information relative to the use of concrete materials, as follows :

(1) A comparison of the crushing strengths of air-cooled blast-furnace slag, limestone, granite, trap rock and gravel, when used as the coarse aggregate in concrete ; tests to be made at the end of 14, 30, 60 and 180 days, 1 year, 2 years, 3 years, 4 years and 5 years.

(2) Determination of the corrosive tendency of sulphur in slag.

(3) Effect of sulphur and other elements on the durability of concrete up to the age of 5 years.

(4) Relative strength and durability of concrete made of high magnesia, low lime slag, and low magnesia high lime slag.

MATERIALS USED.

The materials used as the coarse aggregates in these tests were secured from the following localities :

		Mark.
Slag	Cleveland, Ohio	87,410
Slag	Duquesne, Pa.	87,420
Slag	Youngstown, Ohio	87,430
Slag	Mayville, Wis.	87,440
Slag	Sharpsville, Pa.	87,450
Slag	Cleveland, Ohio	87,470
Slag	Ensley, Ala.	87,480
Slag	Pottstown, Pa.	87,520
Slag	Toledo, Ohio	87,510
Gravel...	Pittsburgh, Pa.	87,460
Trap rock	Birdsboro', Pa.	87,490

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* Engineer of Tests, Pittsburgh Testing Laboratory, Pittsburgh, Pa

		Mark.
Gravel... ...	... Akron, Ohio	87,500
Crushed granite	... Stockbridge, Ga.	87,510
Limestone ...	... Gates City, Ala....	87,540
Limestone ...	... Cleveland, Ohio	87,550

It did not seem practicable to screen the fine aggregate, and recombine, to conform to Fuller's curve, or to use a combination of two or more sands, which would make theoretically the best fine aggregate. The material selected was reasonably well graded and the same sand was used throughout the series of tests, the whole amount being secured at one time, from the back channel of the Ohio River, at Neville Island.

CHEMICAL ANALYSES OF SLAG.

—	Cement Laboratory Numbers.								
	87,410	87,420	87,430	87,440	87,450	87,470	87,480	87,520	87,530
Silica	35·35	36·72	34·35	31·98	35·74	33·63	35·55	31·53	35·15
Alumina	12·28	12·81	13·55	12·25	11·81	13·41	12·04	12·39	14·11
Iron oxide	0·90	1·50	1·02	2·00	0·38	1·25	0·62	0·50	0·25
Manganous oxide ...	0·50	0·61	0·71	0·34	0·70	0·40	0·36	0·22	0·43
Titanium oxide	0·40	0·33	0·50	0·30	0·30	0·40	0·40	0·55	0·45
Calcium oxide	40·05	40·98	45·80	31·75	42·65	39·18	41·35	32·78	38·75
Magnesium oxide ...	8·20	5·14	1·62	19·43	6·18	9·31	8·45	18·24	8·84
Sulphur in calcium sulphide	1·05	1·29	1·10	0·89	1·26	1·03	0·73	0·89	1·11
Sulphur in calcium sulphate	0·52	0·27	0·41	0·27	0·24	0·20	0·50	0·10	0·17
Sulphur in other forms...	—	0·12	—	0·07	—	—	0·05	0·18	—
Carbon	—	—	—	—	—	—	—	0·62	—

The cement used was Alpha Portland. This brand was selected by lot, being drawn from a list of several standard brands of Portland cement. All cement was purchased at the same time, and tested and found to be satisfactory before the preparation of concrete test specimens was begun.

SCREENING AND RECOMBINING OF COARSE AGGREGATES.

As the various aggregates were received, they were screened through iron plates with circular holes, of the following diameters: 1¼, 1, ¾, ½, and ¼ in.

The portions retained on each of the above sieves were stored separately, and labelled, to be later recombined to make the coarse aggregate used in the tests.

The coarse aggregate was recombined to conform to Fuller's curve by weighing equal quantities of the four gradings, and shovelling them together, turning them until their appearance showed them to be thoroughly mixed.

In order accurately to proportion the concrete, the weight per cubic foot of all materials was determined. Since there is no generally accepted method for determining the weight per cubic foot of concrete materials, one was used which had been found in the past to give consistent results. A cubic foot measure was filled loosely with either sand, or the recombined aggregate, after which the measure was dropped ten times on a felt pad 1 in. thick, from a height of 3 in. The measure was again filled and smoothed off with a straight-edge, and weighed. The average of ten determinations was taken as the weight per cubic foot of the material used. The variation of the individual determinations was usually within 0·5 per cent., and seldom over 1 per cent. The weight per cubic foot was frequently redetermined, to take into account any drying out of the material. The weight of the cement per cubic foot was taken at 100 lb., this being a very convenient figure for computations and one frequently used.

PROPORTIONS FOR CONCRETE.

Void determinations were made on the various aggregates, after recombining. Each coarse aggregate was thoroughly wet, drained and a cubic foot measure filled and weighed, as given in the method for determining the weight per cubic foot. Water was then slowly added until the measure was level full. From the increase in weight the percentage of voids was computed.

It was not possible to combine the sand and cement, with the slag, gravel and crushed stone, respectively, to strictly conform to Fuller's curve, and still have tests which would be comparable with each other on the basis of equal proportions of cement. It was, therefore, necessary to determine the leanest mixture which would produce a dense concrete when using the coarse aggregate having the highest percentage of voids, and then using this mixture for all materials. By this method the same quantity of cement was used to make each specimen, and the test data shows a comparison of the different aggregates under the same condition.

The proportions for the motar were determined by making trial mortars of various proportions of cement and sand, and selecting the mixture giving the maximum density as shown by increase in volume of the resulting mortar. After numerous tests, the proportions of 1 part cement and 2 parts sand were found to most nearly fulfil the tests for maximum density of the mortar.

The coarse aggregates used for these tests, varied in weight per cubic foot from 64 to 104·5 lb., and the percentages of voids from a minimum of 31·85 to 49·2 per cent. Since the percentage of voids in one case was 49, to obtain the maximum density, using this aggregate, the mixture should be almost exactly two parts of mortar and four of coarse aggregate, this proportion would give some excess mortar in all of the other cases.

The fact that a 1 : 2 : 4 mixture is one which is very commonly used, and a large amount of data may be found for comparison, was an additional reason for using it in these tests.

These proportions by volume having been selected, the equivalent weight of the materials for these proportions was determined, and throughout the series of tests all materials were weighed and greater accuracy in proportioning thus obtained. The mixture, however, is by volume, the method of weighing being used only to insure more accurate proportions.

METHOD OF MIXING SPECIMENS.

A quantity of material, sufficient to make ten cylinders, was mixed at one time, the sand being spread in a flat pile, and the cement placed over this. The two materials were turned by two men until the colour appeared to be uniform, three or four turnings being required. The coarse aggregate was then shovelled on this material, and the whole turned dry three times. During the fourth turn a weighed amount of water was added from a sprinkling can, and three additional turnings given the mixture. During the last three turnings small quantities of water were added as needed, until a " quaking consistency " was obtained.

In all mixtures an attempt was made to secure the same consistency regardless of the amount of water used. For this reason it was not possible to use a mechanical mixer, as the quantity of water is very important, and in mechanical mixing the material may be made too wet, and the whole batch spoiled for laboratory purposes. It is noteworthy that care must be used to obtain the correct consistency, and that the addition of 1 lb. of water to a 10-specimen mixture would give a consistency too wet, usually described as " mushy," and the results of the tests would be unsatisfactory.

P. T. L. Laboratory No.	Name of Material Used.	Weight per cu. ft. of Material Used.	Per Cent of Voids in Material Used.	14-Day Tests.					30-Day Tests.					60-Day Tests.					180-Day Tests.					One-Year Tests.				
				Mark on Cylinder.	Weight of Cylinder.		Crushing Strength, lb. per sq. in.	Average Crushing Strength, lb. per sq. in.	Mark on Cylinder.	Weight of Cylinder.		Crushing Strength, lb. per sq. in.	Average Crushing Strength, lb. per sq. in.	Mark on Cylinder.	Weight of Cylinder.		Crushing Strength, lb. per sq. in.	Average Crushing Strength, lb. per sq. in.	Mark on Cylinder.	Weight of Cylinder.		Crushing Strength, lb. per sq. in.	Average Crushing Strength, lb. per sq. in.	Mark on Cylinder.	Weight of Cylinder.		Crushing Strength, lb. per sq. in.	Average Crushing Strength, lb. per sq. in.
					Lb.	Oz.				Lb.	Oz.				Lb.	Oz.				Lb.	Oz.				Lb.	Oz.		
87410	Slag Cleveland, Ohio	66.5	49.2	9 18 29	62 62 63	8 10 3	1897 1998 1928	1941	10 33 28	63 63 62	3 10 14	2461 2770 2343	2525	8 13 26	63 62 62	00 15 13	2815 2966 3008	2930	7 5 8	62 62 63	10 5 0	3740 3958 3560	3753	2 16 7	62 62 62	4 10 10	4300 4774 4420	4498
87420	Slag Duquesne, Pa.	78.5	42.74	9 18 28	65 65 65	10 13 8	2212 2318 1946	2159	10 17 27	66 64 65	00 4 1	2425 2983 2562	2657	4 13 22	65 65 65	6 6 4	3143 3402 2810	3117	7 16 25	64 65 64	12 10 5	4280 4464 4200	4315	21 5 8	65 64 65	00 1 11	4824 4544 4808	4725
87430	Slag Youngstown, Ohio	79 3	43.15	9 18 27	65 64 65	4 10 4	2346 2128 1928	2134	10 17 28	65 64 64	8 00 10	2642 2568 2761	2657	7 12 22	66 65 65	4 10 12	3625 3220 3074	3306	2 16 20	65 65 65	10 00 5	3880 4130 4452	4154	1 5 11	65 65 65	8 10 6	5092 5148 4844	5028
87440	Slag Mayville, Wis.	64.5	45.87	2 12 22	62 62 63	12 12 4	2238 2141 2238	2206	3 13 23	63 62 63	00 12 4	2640 2630 2688	2653	5 21 28	62 63 62	5 00 11	3523 3365 3320	3403	1 4 6	62 62 63	15 8 0	4146 4268 4512	4309	14 8 10	62 62 62	6 2 14	4928 4556 5172	4885
87450	Slag Sharpsville, Pa.	75 0	41 53	2 12 28	65 65 64	14 3 14	2477 2380 2594	2484	3 13 27	65 65 65	00 00 00	3127 2999 3100	3075	10 18 21	65 65 64	11 00 13	3359 3468 3268	3365	1 5 9	64 65 64	11 3 11	4906 4678 4824	4803	6 19 17	65 64 65	2 13 5	5397 5660 5108	5388
87460	Gravel Pittsburgh, Pa.	104.5	31.85	2 12 22	69 68 68	2 13 11	2045 2093 2000	2046	3 13 23	68 68 68	13 9 15	2608 2514 2409	2510	6 21 27	68 69 68	13 2 13	3427 3170 3289	3295	7 9 19	68 68 69	14 9 1	4200 3816 3892	3969	14 11 20	69 69 69	3 2 3	4556 4664 4660	4627
87470	Slag Cleveland, Ohio	64.0	46 77	2 12 22	62 62 61	4 4 11	2387 2237 2146	2257	1 11 21	62 61 62	2 8 5	2810 3057 2666	2844	3 14 24	61 62 61	10 1 2	3167 3126 3068	3288	6 13 16	61 61 61	15 14 9	4588 4422 4172	4394	8 23 4	62 61 62	12 11 1	5152 4872 4844	4956
87480	Slag Ensley, Ala.	83.8	42 00	2 10 21	66 66 66	13 00 10	2043 2160 2126	2109	1 11 20	66 66 67	9 00 2	2660 2800 2796	2752	8 17 25	64 66 66	00 9 5	3270 3354 3244	3289	3 4 7	66 66 66	2 9 7	4432 4460 4460	4451	15 12 14	66 66 65	4 3 11	5388 4748 5180	5105
87490	Trap Rock Birdsboro, Pa.	98.7	41 93	2 12 22	72 73 72	8 1 3	2109 2053 2026	2063	1 11 21	72 73 72	6 5 9	2454 2330 2374	2386	9 15 20	72 72 72	6 12 8	3411 3416 3256	3360	3 6 7	72 72 72	15 12 14	4814 4738 4906	4819	4 26 14	72 73 73	9 3 9	4888 4666 5296	4950
87500	Gravel Akron, Ohio	95.0	35.9	2 12 22	68 68 67	00 7 10	1793 1800 1792	1795	1 11 21	66 67 67	13 9 8	2040 2040 2153	2078	8 16 28	67 68 67	12 2 14	2756 2378 2527	2554	3 4 16	68 68 68	3 9 0	3636 3840 3404	3627	5 9 10	67 66 67	4 13 13	3790 3710 3520	3673
87510	Crushed granite Stockbridge, Ga.	90.0	42.34	11 21 22	69 68 69	00 00 8	1980 2178 2208	2122	1 12 22	69 68 69	00 4 8	2230 2334 2313	2292	3 16 19	69 69 69	2 00 8	3112 2760 3258	3043	8 17 23	69 69 69	6 0 5	4190 4016 4248	4151	6 10 24	69 68 69	00 12 2	4740 4422 4738	4633
87520	Slag Pottstown, Pa.	73.75	43.55	1 12 22	63 64 63	00 00 00	2151 2167 2244	2187	2 11 21	64 63 63	2 6 00	2738 2600 2613	2650	5 14 24	63 63 63	8 00 8	3245 3244 3378	3289	27 4 3	63 63 63	5 6 0	4210 4203 4140	4184	18 10 9	63 63 63	10 8 8	4620 4576 4750	4649
87530	Slag East Toledo, Ohio	81.75	42.5	2 12 21	65 66 66	13 14 10	1918 1856 2051	1942	1 11 22	66 65 66	7 4 4	2527 2402 2680	2536	7 16 20	66 66 66	3 5 4	3251 2864 3195	3103	3 9 13	66 66 65	4 15 6	4130 4333 4030	4164	5 X 4	66 67 65	00 2 14	4972 4794 4596	4787
87540	Limestone Gates City, Ala.	94 87	40 33	1 6 7	69 69 71	8 8 0	1670 1750 1720	1713	3 10 23	69 69 69	9 8 8	1985 1950 2030	1988	2 15 22	69 68 69	6 13 00	3149 3014 3072	3082	4 8 9	70 69 68	0 6 12	3936 4636 3814	4127	3 1 6	70 69 70	00 11 12	4340 4344 4348	4344
87550	Dolomitic Limestone Cleveland, Ohio	94.11	38.71	4 13 23	69 69 69	11 7 0	1830 1814 1769	1804	1 12 24	69 69 69	6 14 00	2269 2442 2375	2360	2 17 22	70 69 70	00 12 12	3503 3846 3462	3604	3 19 27	70 70 69	0 0 0	4640 5011 4520	4724	12 25 20	69 69 69	4 2 12	5030 4874 4808	4904

METHOD OF MOULDING SPECIMENS.

The specimens were made in steel moulds 8 in. in diameter by 16 in. high. The concrete was poured into these moulds in layers 4 in. thick, and each layer tamped, or puddled thirty times with a $\frac{7}{8}$-in. round rod. After the second and fourth layers, the sides were spaded with a large trowel. These cylinders were finally finished at the top by spading with a small trowel to form a smooth upper rim, and a piece of plate glass placed on top, to form a smooth surface. Since the concrete would settle slightly after a few hours, it was necessary to cap the top of the specimen with plaster of Paris and cement and again place the plate glass on the cap to make a smooth surface.

The specimens were kept in the moulds for forty-eight hours, and then stored in damp sand for thirty-five days or until tested. At the end of this time all specimens were removed and stored in air. Four short pieces of reinforcing steel were embedded in each of two cylinders from every batch.

These pieces were 3, 6, 9 and 12 in. long, and were cut from $\frac{1}{2}$-in. twisted reinforcing bars having the following chemical analysis :

	Per cent.
Carbon	0·20
Manganese	0·45
Phosphorus	0·018
Sulphur	0·046

These specimens will be examined at the end of the five-year period to determine the corrosive action of the aggregates.

Specimens marked 1 to 10 were made at one time, as were 11 to 20 and 21 to 30.

The results up to one year are shown in the accompanying large table.

DISCUSSION OF RESULTS.

(1) Some of the materials required more careful placing in the moulds than others in order to obtain perfect specimens and to insure all specimens being smooth on the outside when the moulds were removed; a greater amount of time and labour was employed than would be the case if the specimens were prepared in the field. The crushing strengths were, probably, also made somewhat higher.

Each specimen received exactly the same treatment, and all data should be comparable.

(2) The length of time during which this series of tests has been conducted does not warrant the drawing of any definite conclusions, but a general uniformity of the results of the crushing tests of the concrete may be observed.

(3) It will be noted that about one-half of the tests of the slag concrete were made using slag produced by the quick-cooling process, in pits, in which the slag is shipped within a few days from the time it comes from the furnace, and the remainder from slag which had been seasoned in banks for a period of six months in some cases and as much as 15 years in one case.

(4) Slags coming from furnaces many hundred miles apart, varying quite widely in chemical analyses, and also varying considerably in the weight per cubic foot, do not vary in strength in proportion to either the weight or percentage of any chemical constituent.

RECENT VIEWS ON CONCRETE & REINFORCED CONCRETE.

Recent Papers and Discussions.

[The following Paper was read at the last meeting of the American Concrete Institute.—ED.

THE AMERICAN CONCRETE INSTITUTE.

SOME EXPERIENCES ON THE VERMILION CONCRETE ROADS.

By P. C. McARDLE.*

When Vermilion County, Illinois, determined to build its system of county roads by means of an issue of bonds in November, 1914, it had already been determined after consultation with the State Highway Department and the State Highway Engineer of Illinois that the types of road on this system should be either of Portland cement concrete or of cement grouted brick on concrete base.

The superintending of the actual design and construction of this system of roads devolved upon me. I shall not take your time up with any academic discussion of the ordinary methods of concrete road building, but will discuss only some of those of design, construction, and inspection of materials and workmanship which are distinctively those developed in this county.

In 1916 our designs of right angle turns provided for a minimum of 50 ft. radius with 4 in. super-elevation on the centre of curve tapering to zero at P.C. and P.T. respectively. Experience has proved that the minimum should be 100 ft. radius and with a minimum of 6 in. super-elevation carried from P.C. to P.T. and tapering on tangent to zero. On T intersections curves are carried where possible, 100 ft. radius and tapering as before, leaving an angle unpaved between the roads, as traffic on roads previously built showed no sign of using this angle. (See *Fig.* 1).

The original design required that an edger of 2 in. radius should be used on each side of the concrete pavement and a $\frac{1}{4}$ in. radius upon edges adjacent to felt joints Experience has shown that for the protection of the concrete pavement both at the joints and on the sides these have proved wise provisions.

Our entire system of roads was originally divided into nine divisions of approximately 19 miles each, and contracts were let accordingly. A division engineer was assigned to take charge of each division and with such assistance as he might need to properly carry on the work of engineering and inspection, and he was required to give his entire time and attention to the work. Each division engineer was furnished with a complete set of sieves, scales, necessary to make field inspection of coarse and fine aggregates, as well as transit fitted with level bubble, etc., and if in doubt, could refer any sample to our laboratory at Danville.

On several of these divisions crushed stone was used. In these cases, each carload of aggregate was loaded in the presence of our inspector and a test made thereon before material was shipped, and as a result there is on file in our office at Danville a test report of 1,860 carloads of such material delivered during the years 1916 and 1917 which show astonishingly uniform results. The aim of the department was to completely inspect all material called for in the specifications and contract thoroughly. Reports of all inspections were required to be made by the division engineer to the office of the superintending engineer, and all such reports are there kept on file.

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* Superintending Engineer Vermilion County Roads, Danville, Ill.

So far as I know, little has been done heretofore by the engineering profession in the matter of obtaining accurate data on the temperatures upon which concrete roads have been placed, but here a record of the temperature of the atmosphere and of the wet concrete in place is required for every 100 ft. station on the roads. A record of the amount of cement used in each individual station is also required and furnished from day to day to the office.

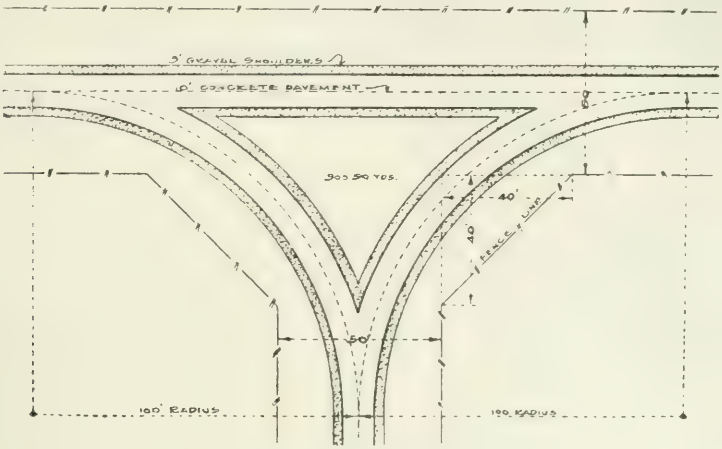

FIG. 1. METHOD OF MAKING A T INTERSECTION.

Cement is tested under a contract with an engineering laboratory after competitive bids. These tests are required to be made on each carload of cement shipped. Samples are taken from cars at the plants and cement is held until preliminary tests are made. The following are the requirements of the contracts for testing cement :—

Chemical Tests :

1 insoluble residue
1 loss on ignition
1 magnesia (MgO) } one on each tenth car.
1 calcium sulphate (CaSO)

Physical Tests :

1 boiling test from each tenth barrel.
1 setting test from each tenth barrel.
1 fineness on a mixture of samples from each carload.
3 tensile tests neat 7 days
,, ,, 1 : 3 7 ,, } on a mixture from each carload.
3 ,, ,, neat 28 ,,
3 ,, ,, 1 : 3 28 ,,

Test reports are made to the superintending engineer of Vermilion County Bond Roads, Danville, Illinois, and to the State Highway Engineer, Springfield, Illinois. Tests are conducted according to the methods laid down in Circular 33, U.S. Bureau of Standards. Tests are made at the respective plants as set forth in contract with the County of Vermilion.

A record is also kept and forms are furnished for the purpose of showing portion of slab covered and how much sprink'ed each day, and if not, why not.

In addition to the tests made by the testing company division engineers are required to furnish samples for test from every tenth carload received on the division. These samples are placed under test in our own laboratory at Danville to check against

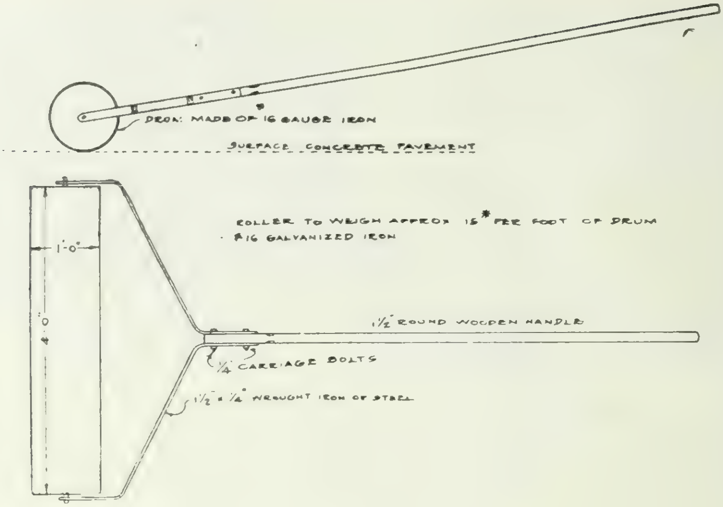
DRUM: MADE OF 16 GAUGE IRON
SURFACE CONCRETE PAVEMENT
ROLLER TO WEIGH APPROX 15# PER FOOT OF DRUM
#16 GALVANIZED IRON
1'-0"
4'-0"
1½" ROUND WOODEN HANDLE
¼" CARRIAGE BOLTS
1½" x ¼" WROUGHT IRON OR STEEL

Fig. 2. Standard Road Roller for Vermilion County Concrete Roads

the test made by the engineering company. In addition, the local representative of the Illinois State Highway Department is also privileged to take samples of cement, coarse or fine, and send them to Springfield to the State testing department for test and report.

In the placing of concrete road under Section 74 of the contract, which required that the finishing should be done with wood floats, it was found practically an impossibility to prevent the ordinary worker or even the expert finisher from making hollow spaces in the concrete road, and on work where crushed stone aggregate was used it seemed to require too much physical exertion to bring sufficient mortar to the surface. Section 74 is as follows : " After the surface of the concrete roadway has been struck off to the proper cross-section, it shall be finished with wood floats. The wood floats shall be used only to flush mortar to the porous places in the surface, and great care

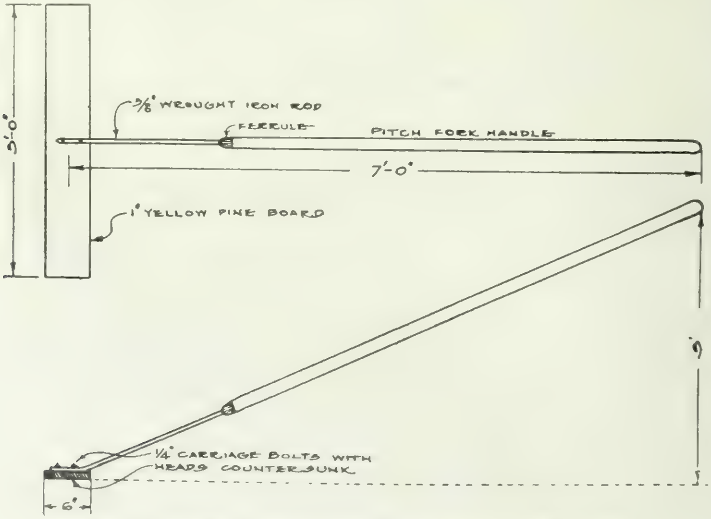

Fig. 3. One Type of Handfloat used in Vermilion County.

must be taken not to rub hollow places in the surface. The wood float finish shall be made as soon after the concrete has been deposited as possible, and in no case shall the finishing be delayed until the concrete has taken a set."

Appeals to inspectors or to division engineers and injunctions to the contractor failed to make enough impression to get the work done as it ought to be. Accordingly it was early determined to use other devices. Our experience indicated that the use of the hand float or the long handle float with a circular rotary motion was an ideal method of making water pockets in the pavement. It was found that the tendency on every job was to add too much water to the mix, and this latter finally determined us to experiment with other devices with a view to eliminating these defects. Accordingly belts were tried in conjunction with the long handle float with the requirement that the long handle float should be used only in a transverse direction across the slab. A combination of the belt and long handle float used in this manner improved the work somewhat, but was not entirely satisfactory.

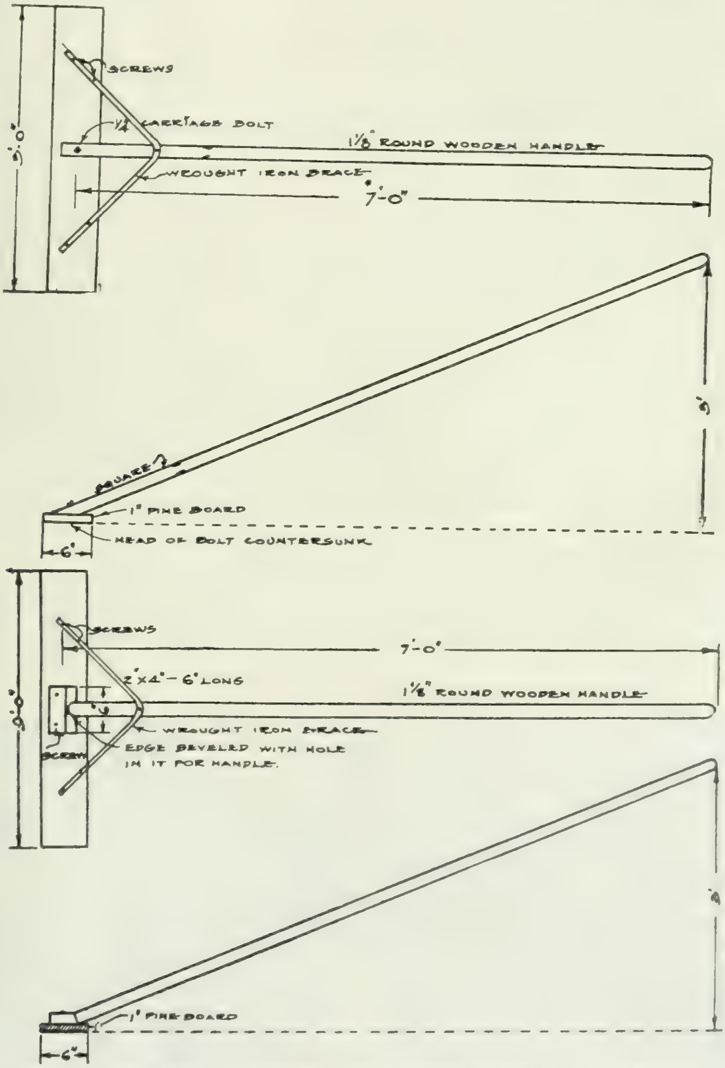

Fig. 4. Two Types of Handfloats for Vermilion County Concrete Roads.

Accordingly it was determined to try a roller of the type designed by Colonel Gaillard, City Engineer of Macon, Ga. (Details of the float and roller are shown in *Figs.* 2 to 4). On our widths of road this type of roller, in conjunction with the long handle float, proved an immediate and unqualified success, and since that time every one of the contractors has purchased a roller and long handle float for this purpose although not required to do so by the contract or our specifications. The roller gives better work in many other respects, not the least of which is the elimination of hair cracks due to high wind or heat, or both, in addition to preventing the hollow spots referred to before, caused by the circular motion of either short or long handle floats.

I have personally driven over miles of road finished with the roller and long handle float immediately after a rain and have not found as much as one depression upon the entire distance.

Our contract in regard to joints in concrete roads requires that " whenever the temperature of the atmosphere exceeds 70° F. joints shall be provided at intervals of 200 ft. Whenever the temperature is less than 70° F. joints shall be provided at interval of 100 ft."

Whether due to the fact that the concrete placed at the lower temperature was better concrete (all were laid with equal care and supervision), or from the fact that the joints were spaced closer, it is a fact that fewer cracks have occurred in the concrete roads when the joints were placed 100 ft. apart than when placed 200 ft. apart. Placing joints as designed was decidedly empirical, as there was no general agreement between engineers but rather a radical difference on the question whether joints should be used at all in rigid types of road.

After considerable experience, both in the State Highway Department of Illinois and as superintending engineer of Vermilion County, I have no hesitation now in saying that joints should be placed much more frequently and of a wider type than recommended. The spacing and thickness of joints as shown in this section of our specifications was based only upon the coefficient of expansion of concrete due to heat alone and for a range of 60° F. Expansion due to moisture or crystallisation was not considered, and while this has not yet been definitely determined there is strong evidence bearing on the subject from several sources that expansion due to moisture content is as great or greater than that due to heat, and, accordingly, I believe a sufficient number of joints should be made to prevent any stresses in the slab due to expansion from either moisture or crystallisation or expansion due to heat or both. While the concrete slab may within itself be strong enough to resist internal stresses due to expansion once in a while, there can be very little doubt that repeated internal stresses, however slight, destroy the cohesion and adhesion of the aggregates in a concrete structure if adequate provision is not made for such expansion.

Fifty miles of the concrete roadways of Vermilion County have now been in service two seasons, and although I do not believe the work was nearly as well done as in 1917, they have given very good satisfaction and show small signs of deterioration. Repeated examinations of the roller completed roads, however, show an exceedingly more dense surface.

Part of an 80-mile Concrete Road in West Virginia.

GLEANINGS FROM THE ENEMY PRESS REGARDING CONCRETE AND REINFORCED CONCRETE.

It has been deemed advisable that some particulars of the trend of enemy activities in technical matters should be known in this country. The following extracts taken from the Enemy Press, are partly from "Beton und Eisen" and partly from other enemy papers, with the view of keeping our readers posted as to what is occurring in these matters.—ED.

DOES THE CRUSHING STRENGTH REALLY SHOW THE QUALITY OF CONCRETE?

In a paper recently published in *Beton und Eisen*, by Dr. Emperger, the question is raised as to whether the crushing strength of a concrete is a true indication of its quality. According to a widespread custom, specifications demand that the cement or concrete shall attain a given crushing strength after one, four, or six weeks. The result is that preference is given to fat mixtures which rapidly develop a high crushing strength regardless of their durability. Why, for example, should a concrete with a crushing strength equal to that of average brickwork be regarded as useless, and what purpose (other than the necessity of a rapid test) is there in insisting on so high a crushing strength in so short a time? Unless there is some underlying reason of great and permanent value this practice of expecting a rapidly developed and excessive resistance to crushing may have serious consequences. A softer concrete of much lower crushing strength than the customary 2,380 lb. per sq. in. has a greater elasticity and is far less brittle than standard concrete and is consequently less liable to be cracked under ordinary conditions of use, nor is it even likely to reach this brittle condition.

It is an error, common to all specifications, to assume that the factor of safety of a structure may be increased to an unlimited extent by the use of concretes giving high crushing tests. Cement alone is useless as a building material, notwithstanding its high crushing strength, and the value of concrete lies in the addition of the aggregate so as to form a combination without the defects of either constituent alone.

Among other serious defects of very fat concretes, the one on which attention has specially been concentrated, is the shrinkage. To avoid this, as well as to prevent a wanton wastage of cement, it is necessary to avoid an excessive proportion of cement in the concrete. A further disadvantage in the use of too rich a concrete is the manner in which it cracks some time after its completion. These cracks occur in spite of the high crushing and high tensile strengths of the concrete and are as noticeable in solid ground floors as in beams and other structures, so that they are quite independent of the external strains to which the concrete may be subject. When a lean concrete cracks—which is much less frequently than a rich one—the cracks distribute themselves so uniformly throughout the material that they are not nearly so serious as the larger fissures in a rich mixture. Moreover, a lean concrete which only attains its maximum strength very slowly will yield to any settlement strains, whereas a richer and quickly maturing concrete can only relieve itself by unsightly and sometimes dangerous cracks. A further advantage of lean concrete is that it can be repaired more satisfactorily.

According to Dr. Emperger, the present practice of demanding high crushing tests would be abandoned if a careful and authoritative investigation were to be made on the lines of Bach's experiments. In his opinion the extended use of lean concretes is not merely a means of reducing the cost of construction, but it is to be recommended for scientific and technical reasons. This being the case, it is foolish to close one's eyes to the facts, when once they have been ascertained, and the sooner the advantages of lean concrete are known the better will it be for all concerned

THE ANNUAL REPORT FOR 1917 OF THE GERMAN CONCRETE ASSOCIATION.

THIS Report contains numerous references to technical matters relative to the use of concrete for military purposes and the outlook with respect to reconstruction and the charges which may be expected to occur in the use of reinforced concrete in various industries. It also deals with numerous commercial and social matters relating to the industry—a welcome addition, as these important subjects have not hitherto received the attention they deserve. The technical section of the Report contains an important paper by Dr. Birkenstock, who has inspected numerous reinforced concrete structures in the war zone, and reports that reinforced concrete is better than any other building material for affording protection against shot and shell fire. (Details cannot, of course, be published at present.)

The German Committee for reinforced concrete has instituted investigations (at a cost of £15,000) on the shearing stresses in flat beams, and the development of large slabs of material pierced for openings where necessary, and other researches on parts of buildings which are supplied ready-made in reinforced concrete, the preparation of a mortar to close tension cracks effectively, corrosion experiments and researches on concrete ships. The Association decided not to proceed with a proposal to stiffen the specification of the metallic reinforcement. It has devoted some attention to the production of standards for slag cement, the addition of trass to cement and to numerous other technical matters. It has made an official pronouncement on the much-debated subject of grain silos, has collected information from all its members on the use of concrete in building ice-stores and has investigated the destruction of concrete by gas-water.

In the technical portion of the Report are short summaries of the investigations made by the various technical committees. These were naturally limited by the condition of affairs at that time, due to the war, and a large part remains incomplete. Only those investigations which are definitely connected with the war have made definite progress. A special report was made of a " Study of the Possible Uses of Concrete in Fortifications and Supports," by Dr. Birkenstock, who has visited a number of reinforced concrete structures, and who has published therein the instructive conclusions he has reached with respect to the behaviour of concrete when subjected to the action of shot and explosives. A smaller committee, by favour of General Bock in Brussels and Admiral Schröder in Brügge, inspected the buildings in Belgium right up to the furthest scene of operations. This inspection was made under the guidance of Privy Councillor Lorenz-Meyer and also afforded an opportunity of examining a series of important civil structures commandeered for war purposes. It must suffice for the present to say that the result was entirely favourable to reinforced concrete and showed that reinforced concrete behaves better than any other building material and affords protection against the heaviest grenades and shells. The complete report of the investigation cannot be published until after the war.

A REINFORCED CONCRETE ROOF COLLAPSES.

A factory building, 25 ft. wide internally, was covered with a saddle-back roof having a vertical height of 4 ft. between the ridge and eaves. Three tie-beams of 23 in. by 12 in. cross-section, placed about 17 ft. apart, supported a roof of hollow blocks 3$\frac{1}{4}$ in. thick covered with a 2 in. layer of reinforced concrete. The ends of the tie-beams rested on a ledge 10$\frac{1}{2}$ in. wide at the top of the walls of the building, the walls being 15$\frac{1}{4}$ in. thick. Under each tie-beam was a wall-plate 2$\frac{1}{2}$ in. thick and 3 ft. wide. The building was erected by a contractor who sub-let the concrete work to another firm who had specified the dimensions of the tie-beam, and this specification had been approved by the local authority. In it the tie-beams were designed as horizontal beams lying freely on two supports, but no allowance was made for the horizontal shear (which was bound to result from the bent form) or for the best development of the shoulder.

The roof was concreted between May 10th and 21st. According to regulations the tie-beams should remain enclosed in the shuttering for three weeks and the joists for a fortnight longer, but the whole of the shuttering was removed on June 7th, and half an hour after the roof began to collapse. Fortunately this was seen at once, so that the men were able to escape and no one was injured. The shoulders of the tie-beams were completely destroyed ; the concrete was wet and contained numerous hollows ; it was also too soft. The walls were forced outwards and had to be rebuilt. The two contractors willingly undertook to do all the necessary repairs and rebuilding free of charge.

CONCRETE SHIPS.

The Concrete Shipbuilding Co., of Hamburg, has accepted an order for a floating dock 240 ft. long, 83 ft. wide internally, and 113 ft. externally, with a capacity of 5,760 tons. This dock is one of three, the total length of which will be 720 ft., and the total capacity 18,000 tons. The ends are calculated to carry a load of 80 tons per yd., whilst the centre is designed for a load of 150 tons per yd.

LIGNO-CONCRETE.

In the August issue of *Beton u. Eisen* reference is made to the use of ligno-concrete for building cheap houses. Wood is used as the reinforcement to the concrete. The wood may be of otherwise little or no building value, such as small, peeled unseasoned, round pieces. These must be completely buried in the concrete. Both the inner partition walls and the roof are constructed in this way ; but for the latter small-meshed wired netting, nailed on the underside, is used and the concrete is made somewhat stronger. A specimen cottage built by Ph. Gelius, architect to the Local Commission at Munich, has been approved by the authorities.

CONCRETE IN SEA WATER.

In *Hansa* (September 14th) it is reported that German authorities are of opinion that no protective composition is necessary for the hulls of reinforced concrete ships. German Government tests on works on the island Sylt confirm this view. No growths have occurred on concrete constructions with smooth surfaces.

CORRESPONDENCE.

Under this heading we invite correspondence.

CONCRETE-SHIP BUILDING YARDS.

To the Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

SIR,—At the present time when strenuous efforts are being made by the Empire as well as her Allies to overcome the loss of shipping due to the action of the German U-boats, it is much to be regretted that in several of those shipbuilding yards in the United Kingdom where concrete ships, etc., are being constructed, there is a marked indifference on the part of nearly everybody concerned to the necessity of safeguarding the plant and ships in building from the ravages of fire.

It will be conceded by all that there is a considerable quantity of timber used in the construction of these vessels in the way of forms or shuttering and scaffolding. This constitutes a serious fire risk, to which must be added the large amount of wood shavings and waste incidental to such work. In addition there are the saw mills and joinery shops in which the greater part of the woodwork is prepared, and these have their own severe fire hazard. More often than not such shops are contiguous to the slipways, so that a fire in either the workshops or slipways would easily and readily spread from one to the other so that the whole of the shipyard would be jeopardised.

Cannot something be done to awaken the proprietors of the yards to the necessity of so designing them and providing them with fire appliances that should such a dire event happen, as assuredly it will unless immediate steps are taken to remedy these defects, the fire would be confined to one small portion.

Not only is it desirable to urge these important considerations on the owners, but their employees from the chief to the humblest of the staff should be impressed with the importance of the necessity, at this time of the country's need, of exercising the greatest care to prevent such a calamity arising.

Probably the fact that the ships are being constructed of concrete, which is generally considered as being "fire proof" has something to do with this neglect, but this idea should be put entirely out of mind, and serious attention given to the points raised above.

Yours truly,

FOREWARNED, FOREARMED.

THE CORRECT PROPORTIONING OF CONCRETE.

To the Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

SIR,—Being very interested in the subject of "corrected" concrete—which was dealt with by Messrs. Johnson and Kingston in your September issue—and feeling that the matter is an important one, I would like to deal with one or two points raised by Mr. Cecil H. Desch in his letter which was published in your last issue.

Mr. Desch gives an excellent illustration of the need for a properly graded aggregate, and there is no doubt whatever that research work is necessary to determine the proportions and methods of mixing in order to obtain as dense a concrete as possible, but at the same time the results obtained by Messrs. Johnson and Kingston, while praiseworthy as indicating investigation in this important matter, cannot be considered as conclusive because the proportion of water used in mixing was not constant.

The very interesting papers on Concrete in Sea Water by Messrs. Wig and Ferguson are referred to by Mr. Desch in support of his remarks, but, if I may be allowed to quote a few sentences from the article by these gentlemen in the October issue, I think it will be seen that, although correct proportions are important, the quantity of water used in mixing is a factor which will determine the density and strength of the concrete. The sentences referred to are as follow :—" The amount of water used in mixing is of even greater importance, perhaps, than the proportioning of the concrete. This is particularly true for sea water work." " The effect of the consistency employed on the ability of the concrete to resist sea water action was forcibly emphasised in many instances during the examination made by the writers." The authors then give a description of some work which was executed with concrete mixed with different quantities of water, and in conclusion they state :—" Here we have three specimens of concrete of similar ingredients exposed to the same conditions, the only variable being the amount of water used in mixing. The very dry and the very wet concrete have been decidedly unsatisfactory. That of a medium consistency has successfully resisted disintegration under severe exposure."

Again, they say :—" It is evident that the amount of water used in mixing concrete exposed to sea water action has a most important bearing on the durability of the structure. *Either too dry or too wet a consistency will cause failure."*

The authors of the paper also state that it is generally advisable to use richer mixtures than would be used for similar structures on land. In face of this evidence of the great importance of the quantity of water used in the mixing it will be clear that no tests for " corrected " concrete can be of real value as a comparison with 1 : 2 : 4 mixtures unless this factor is taken into consideration.—Yours faithfully,

ALBERT LAKEMAN.

Birmingham, *October 22nd*, 1918.

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NEW BOOKS
AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

Mathematics for Engineers. By W. N. Rose, B.Sc.

London : Chapman & Hall, Ltd. Vol. I., 510 pp. Demy 8vo Price 8s. 6d. net.

There are not many questions with respect to the education of engineers which have been ventilated so freely as that of the training in mathematics which should be given to engineers. Although it may be regarded as a matter of regret, it is nevertheless a fact that most engineering students do not derive much benefit from the lectures given by professors who are "pure" mathematicians. Yet for many years such training was almost exclusively in the hands of such professors, with the result that the engineering students finished their courses with very little acquaintance of mathematics.

During the last fifteen years it has become the practice to give to engineering students a training in mathematics, specially designed to approach the subject from the standpoint which will enable the engineers to apply the results to the problems which arise in practice, and Mr. Rose's book is one of a number of attempts to provide a textbook to assist such a training. The general result of this attempt is an excellent one ; the style is concise, yet adequate, and the treatment is assisted by a large number of numerical examples which are very helpful to those students who rely entirely upon books for their study.

The diagrams are good and clear, and the general make-up of the book reflects great credit upon both author and publisher.

After some introductory data, the book opens with a chapter upon Aids to Calculation, in which methods of approximation and the use of logarithms are explained. The next chapter deals with Equation in a lucid manner ; following this is a chapter on Mensuration, which is very good indeed, although it compresses a large amount of subject matter into a small amount of space.

An introduction to the subject of Graphs forms the subject matter of the fourth chapter ; this chapter might, we think, have come rather earlier in the book in view of the fact that so much of an engineer's work deals with Graphs.

After a chapter on Further Algebra—dealing with progressions and the theory of logarithms—we come to an easy chapter on Plane Trigonometry. We then have in succession chapters upon Irregular Curved Figures, Calculation of Earthwork Volumes, Plotting of Difficult Curve Equations, the Determinations of Laws, the Construction of Practical Charts, and various Algebraic Processes.

The chapter on the Construction of Practical Charts contains some valuable subject matter not commonly met with in textbooks.

The book is full of numerical examples, so full that we think that there is some danger of there being not enough of principles or theory in comparison with the application. After all, the great educational value of mathematics for an engineer consists in the training in principles and in inculcating a certain outlook, and students who spend most of their time in working out "practical problems" do not get a sufficient general grasp of principles to enable them to attack unfamiliar problems.

Tables of Safe Loads on Steel Pillars. By Ewart S. Andrews, B.Sc., and W. Cyril Cocking, M.C.I.

London : James Selwyn & Co., Ltd., 20 Essex Street, Strand. 25 pp. + xxxiii. Price 6s. net.

This handbook is published for the use of engineers, architects, and builders to facilitate the design of steel pillars, and the tables have been prepared to comply with the requirements of the London County Council (General Powers) Act, 1909.

The introduction forms an important feature of the volume, as herein are given notes on the general design of pillars, the consideration of formulæ, the tabulation of calculations, correction coefficients for other formulæ, and other very useful matter.

The authors have introduced a column for "unit slenderness ratio"—*i.e.*, $\frac{12}{g \text{ mm.}}$

and this enables the slenderness ratio of a given pillar to be found at once by multiplying its length in feet by the quantity. The tables are given for pillars having one end fixed and one end hinged, as this is the most general condition called for in the calculations of ordinary pillars in steel frame buildings, but the loads for other conditions can be quickly found by following the methods set out in the tables.

The first table gives the safe loads for unplated standard beams used as pillars, and this is followed by tables for plated pillars, wherein the most suitable sections are given with varying size plates, one to each flange.

These tables are very useful, and they will be more so when the authors are in a position to publish corresponding tables for other sections, as they state it is their intention to do when the opportunity occurs. It will be clear that the designer so often requires to continue the same section of beam through several floors, with the addition of extra flange plates as required to take the additional load, that full value cannot be obtained from this book until the other tables are available to enable him to design a pillar n this way for the full height required.

Selwyn's Metric Conversion Tables. Edited by W. Erskine Dommett, A.F.Ae.S.

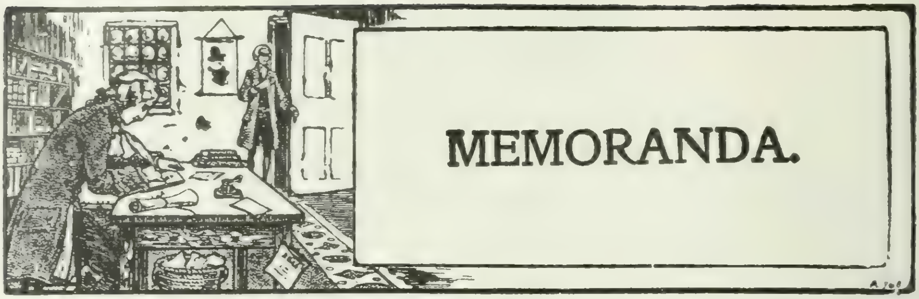
London : James Selwyn & Co., Ltd., 20 Essex Street, Strand. 49 pp Price 2s. 6d. net.

The metric system is likely to be used to a large extent by engineers immediately after the war, as it will be necessary to conform to Continental methods when dealing with schemes on the Continent, and this little volume will be extremely useful, and enable considerable saving of time to be effected by the designer who has been trained to think in feet and pounds.

Some general notes and useful constants are given for conversion, and the remaining matter consists of thirty-one useful tables, giving the equivalents of English weights and measures in the metric scale. In preparing the book, the requirements of men engaged in the various branches of engineering and science were kept specially in view, and the tables common to these branches are given fully, whereas the lesser used tables are given in an abridged form. A considerable amount of labour must have been involved in the preparation of the tables, as will be realised when it is stated that the first three tables are as follows : (1) Equivalents of Millimetres in Inches (advancing by fractions) ; (2) Equivalents of Millimetres in Inches (advancing by decimals) ; (3) Equivalents of Inches (advancing by fractions) in Millimetres. These form a typical example of the thoroughness that has been pursued throughout as the equivalents are given in both ways, and thus the required figures can be quickly found. It is a little volume that can be recommended to our readers as being well worth the published price.

MEMORANDUM.

The Concrete Institute.—The first meeting of the Session 1918-1919 will take place on the 28th November, when Mr. H. D. Searles-Wood, F.R.I.B.A., will give his presidential address.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome. —ED.

Pre-cast Concrete Lumber for Mine Work.—In a recent number of *Engineering News-Record* there appeared some interesting particulars on the use of concrete in an American mine. The writer of the article gives the following account :—

During the past four years considerable precast concrete "lumber" has been used by the Oliver Iron Mining Co. in the relining of its shafts on the Vermilion and Mesaba range in Northern Minnesota. A concrete plant was started in 1914 at Hibbing, and 450 complete shaft sets have been manufactured and shipped to all parts of the range.

Where a new shaft is to be lined with pre-cast lumber it is excavated and constructed in much the same way as the ordinary timbered shaft. The surface of the ground is levelled and two trenches 4 to 6 ft. deep, depending upon frost depth, are dug for reinforced concrete bearers 18 by 24 in., which support the shaft lining. These trenches are 20 ft. apart and 34 ft. long.

Cross-bearers of structural steel consisting of two 15-in. 33-lb. channels are placed under each wall plate. Under each divider the cross-bearer is one 15-in. 42-lb. I-beam. Channels are used under the wall plate so that hanging bolts may be placed in between. Immediately on top of the bearers is placed the first shaft set, consisting of two wall plates 20 ft. long, two 8-ft. end pieces, and two dividers 6 ft. 3 in. long. All of these are 12 in. square in cross-section, except that the dividers are 10 by 12 in. Forms are then built up for placing the concrete for the collar, which is from 6 ft. to 8 ft. in height, extends directly above the shaft set and prevents water and *débris* from falling into the shaft. Pockets are left in the collar for nuts for hanging bolts. As the earth is excavated it is placed around the collar.

The shaft sets are horizontal and are spaced 5 ft. apart. Each set is supported by twelve $1\frac{1}{2}$-in. hanging bolts, two in each end piece and four in each wall plate. Each set weighs approximately 10 tons, including the concrete lining slabs or lath. Posts or stuttles separating the sets are made up as follows : Four corner stuttles, 4 ft. long and 10 in. square, and four centre stuttles under dividers, 4 ft. long and 8 by 10 in. Between sets there are eight 3 by 10-in. slabs and thirty-eight 3 by 10-in. slabs, all 4 ft. $2\frac{3}{4}$ in. long. These slabs are fitted in on the exterior side of the sets, being held in position by a 3 by $1\frac{3}{8}$-in. groove in the wall plates and end pieces and by the earth which is packed in behind the lath.

The 20-ft. wall plates are first lowered into position and the end pieces fitted over them. The stuttles are then put in place, after which the hanging bolts are placed in the proper holes. When the whole set is in position and lined up, the bolts are tightened and the lath shoved into position. Most of the shafts lined with pre-cast lumber on the Mesaba range are about 200 to 300 ft. deep.

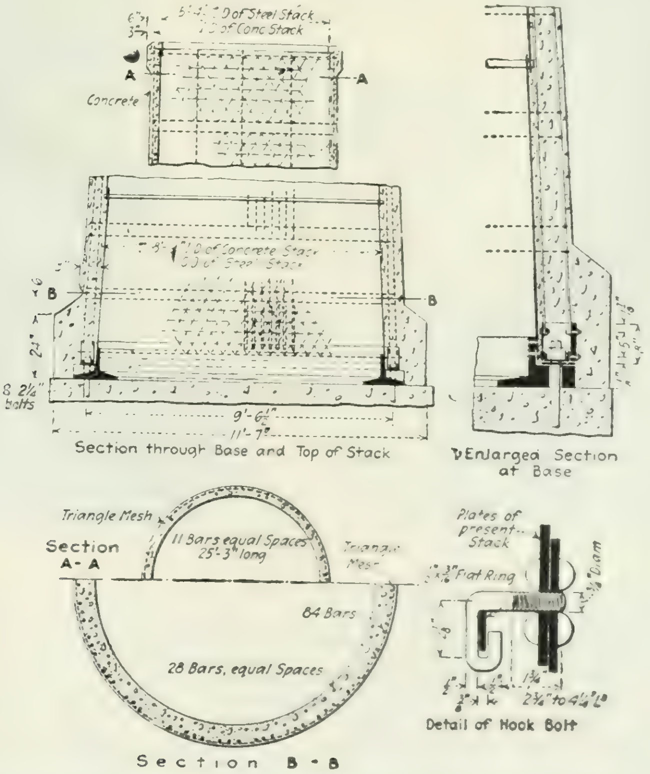
The usual type of shaft used by this company has three compartments ; a ladderway 6 by 6 ft. 4 in. and two skipways 5 by 6 ft. in the clear, with dividers in between, making the over-all dimensions 8 by 20 ft. At Spruce No. 4 there are five compartments. This shaft is now being sunk from a 240-ft. level to the 400-ft. level by the same method as described for other precast shafts. From the old 240-ft. level upward the shaft was relined in 1916 by the use of pre-cast members. In this method jacks were used to hold up the concrete members until the end members and slabs were put in place along with the stuttles or posts. With the stuttles exactly 4 ft. long the end pieces and wall plates were fitted in at the corners so as to form a perfect joint. The dividers are notched at the ends into a dovetailed shape so as to fit into the wall plates. Ladders at the Spruce shaft are all of steel, as are the landing platforms. Between the compartments 6-in. wire mesh is used for protection.

Cost data tabulated during 1914 and 1917 show that concrete sets can be manufactured at a cost practically double that of timber. The cost of installation is a little higher, due to increased weight. The ordinary timber shaft must, however, be replaced within six or eight years, while a concrete shaft has an indefinite life, besides being fire-resisting.

Besides concrete lumber for mine shafts, concrete blocks and concrete pipe have been made in large quantities.

Rusting Steel Chimneys Coated with Concrete by Cement Gun.—Five steel stacks at the Pittsburgh Crucible Steel Co.'s Midland works, which had become very badly corroded in service, were recently covered entirely on the outside with a reinforced concrete shell at a comparatively low cost and without putting the stacks out of service, except for a few days. The concreting was done with the cement gun, operated by a workman standing on a scaffolding in the first two chimneys, and in the more recent work on a hanging scaffold.

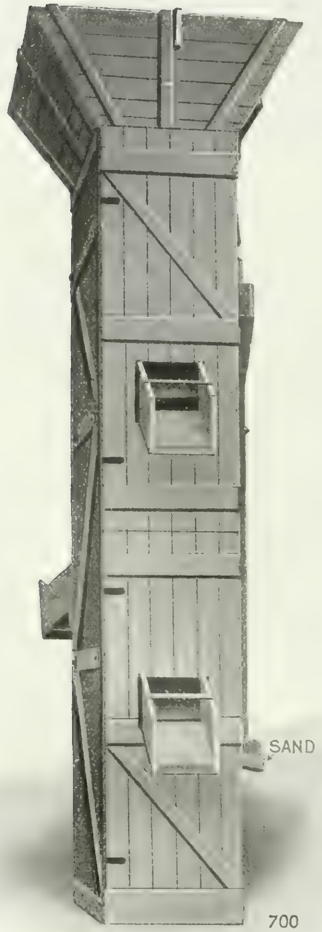
The stacks are 125 ft. high, approximately 6 ft. in diameter at the top, and with an outside diameter of 12 ft. at the footings. The coating comprised a self-supporting annular ring of reinforced concrete, varying in thickness from 8 in. at the base to 3 in. at the top, the reinforcement being securely fastened to the steel plates of the stack itself. At each ring of the stack—that is, at vertical intervals of about 5 ft.—hook bolts were tapped into the plates of the stack. These plates carried horizontal steel



Details of the Reinforcement for the Cement Gun Coater Chimneys.

"ZENITH" SAND & BALLAST WASHER

(Pleasances' Patent).



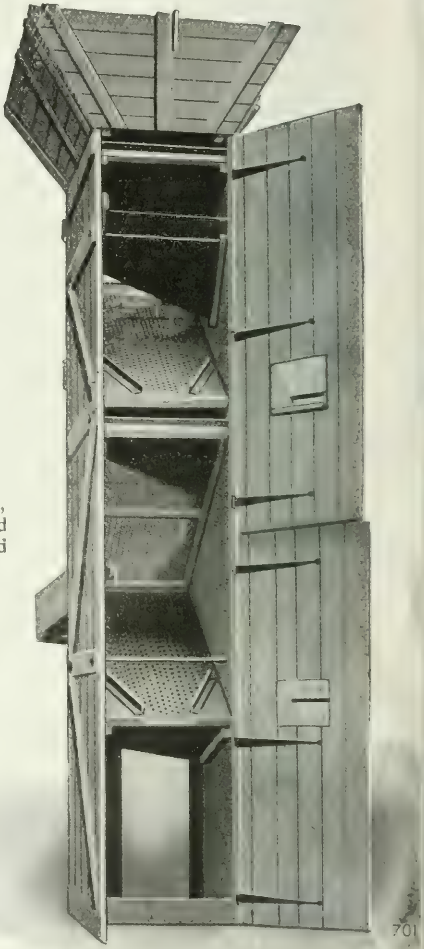
Capacity :
20 yards per hour.

○

Water used :
3,500 gallons.

○

Used by H.M. War Office, Messrs. Walter Scott and Middleton, Limited, and many others.



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bands held a fixed distance about 2 to 4 in. away from the shell. These bands, in turn, carried vertical reinforcing rods of square twisted steel, around which was wrapped the annular ring of the wire mesh employed. The mesh varied in spacing and size of wire with the thickness of the concrete to be applied. In the lower 20 ft. two rows of vertical rods were placed, the wire mesh being attached to the outer row. Above the 20-ft. height the one row of vertical rods which carried the mesh was placed near the outer face of the concrete.

The concrete was applied through the cement gun on to and through the wire mesh. A compressor with the cement gun was installed in a near-by house, and the hose with the nozzle was carried up as the work went along. The stacks were kept in operation during the work, except for a few days on each while the concrete was being applied to the upper part.

About 20 to 25 ft. of concrete was applied a day. Each stack required 11 cu. ft. of finished concrete, reinforced with about 1½ per cent. of steel.

Effect of Positive and Negative Ions on Concrete.—Some experiments have been made with a view to ascertaining the influence of various salts on the setting of cement. An account of these tests is given in a recent issue of the *Philippine Journal of Science.* Tests were carried out with four cements and eleven salts under similar conditions—chlorides (Na, Zn, Cw), nitrates (Na, K, NH), sulphates (Na, Zn, Cw), and bicarbonates (Na, K). The effect was generally to lower the tensile strength, and any increase usually associated with sulphate was very small. The cement with the highest content of calcium appeared to be affected the most. The sulphates and chlorides of zinc and copper caused a retardation in the initial set, which increased with concentration. The other salts caused a varying retardation which reached a maximum and then diminished. The positive ion seems to have the greater influence, which would naturally be expected, inasmuch as it would affect the ionised calcium.—*Chemical and Metallurgical Engineering.*

Concrete Tanks.—It is reported in *Concrete,* of U.S.A., that concrete tanks have been built in Chile for holding solutions incident to copper refining. Not only have they withstood this service, but severe earthquake shocks have not harmed them.

Concrete Freight Cars.—In a recent issue we referred to some experiments that are being made in South Wales to construct concrete rolling stock. We now learn that similar experiments are being carried out in America, where a trial freight car is being constructed in the yards of the M. E. White Paving Co., Chicago.

The Protection of Seaports in America.—It is proposed in America to protect exposed seaports by means of walls of concrete laid in the water.

Concrete Bulkheads.—In connection with an interesting piece of salvage work just completed by the Salvage Section of the Admiralty, concrete bulkheads were used for rendering a badly damaged vessel watertight. We give the particulars of the salvage work as they appeared in the *Bulletin* :—" The steamship *Araby*, of about 3,300 tons register, with a cargo of oats aboard, ran aground on the French coast on December 21st, 1916. The vessel was refloated on December 23rd, and whilst being assisted into a harbour the towing hawsers parted. The forepart of the steamer ran up on to one of the harbour piers, and the after end on to the other pier, causing the ship to become firmly fixed fore and aft athwart the harbour entrance.

" A few hours later the steamer broke her back. The stokehold, engine-room, and No. 2 hold filled rapidly, and the water also gained access into Nos. 3 and 4 holds. The vessel's decks, with the exception of the poop and forecastle decks, were submerged at high water.

" Salvage operations were commenced immediately, the wreck being subsequently lifted, partially by camels and partially by pumping, and taken up harbour. The *Araby* then broke in two, being held together only by a few deck plates, &c. These plates were cut apart by oxy acetylene gas, and the two halves filling they settled down on an even keel.

" By January 18th, 1917, both halves were refloated and beached inside of the harbour clear of all traffic. They were allowed to lie in this position until this summer, when steps were taken to remove the wreck. In the meantime the two halves of the vessel had been made watertight by the erection of concrete bulkheads at the after end of the fore half and the fore end of the after hold. In July the two halves were prepared for sea. By August 15th both halves were refloated and were towed across the Channel to a repairing yard on the Thames, where preparations have been made to reconstruct the ship."

TRADE NOTES.

All architects know that it is generally the little defects which ultimately cause annoyance to their clients.

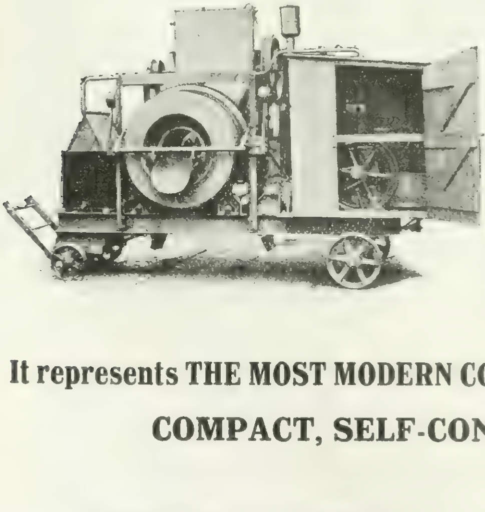
For instance, a flooded stokehole causes endless discussion, because everyone occupying the building remarks on the absence of warmth. In some cases continual flooding will entirely rust through the boiler, making it useless after a few years. This was the case at the Beaumont Schools, Warrington, for the boilers connected with the heating apparatus were destroyed owing to the continual flooding of the stokehole for a period of eight years. The surveyor seriously contemplated filling in the chambers to above the flood height, but two months before the great war he decided to try waterproofed cement for the concrete in the floor and wall rendering

We have a recent report stating that the Pudloed cement treatment has produced a perfectly dry cellar during the four years which have elapsed since the work was done.

Winget, Ltd.—In consequence of the rapid growth of their business as manufacturers of concrete machinery, Messrs. Winget, Ltd., have added a North of England office to their numerous branches at home and abroad. The address is 40, Albert Road, Middlesbrough, where Messrs. Winget's late Secretary, Mr. Calvert Griffiths, acts as manager.

PUBLICATIONS.

Conversion Tables for Temperatures.—There has recently been published by the Cambridge Scientific Instrument Co. a spiral chart for converting temperatures from Centigrade to Fahrenheit or *vice versa*. The chart is mounted on stiff cardboard measuring 12 in. by 14½ in., and contains a column of useful data regarding standardising points, melting and boiling points, steam temperatures, specific heats, densities of water, thermal conductivities, and quenching and tempering bath mixtures. These cards will be sent free to anyone interested on receipt of four penny stamps to cover postage, and applications should be addressed to the Cambridge Scientific Instrument Co., Ltd., Cambridge.



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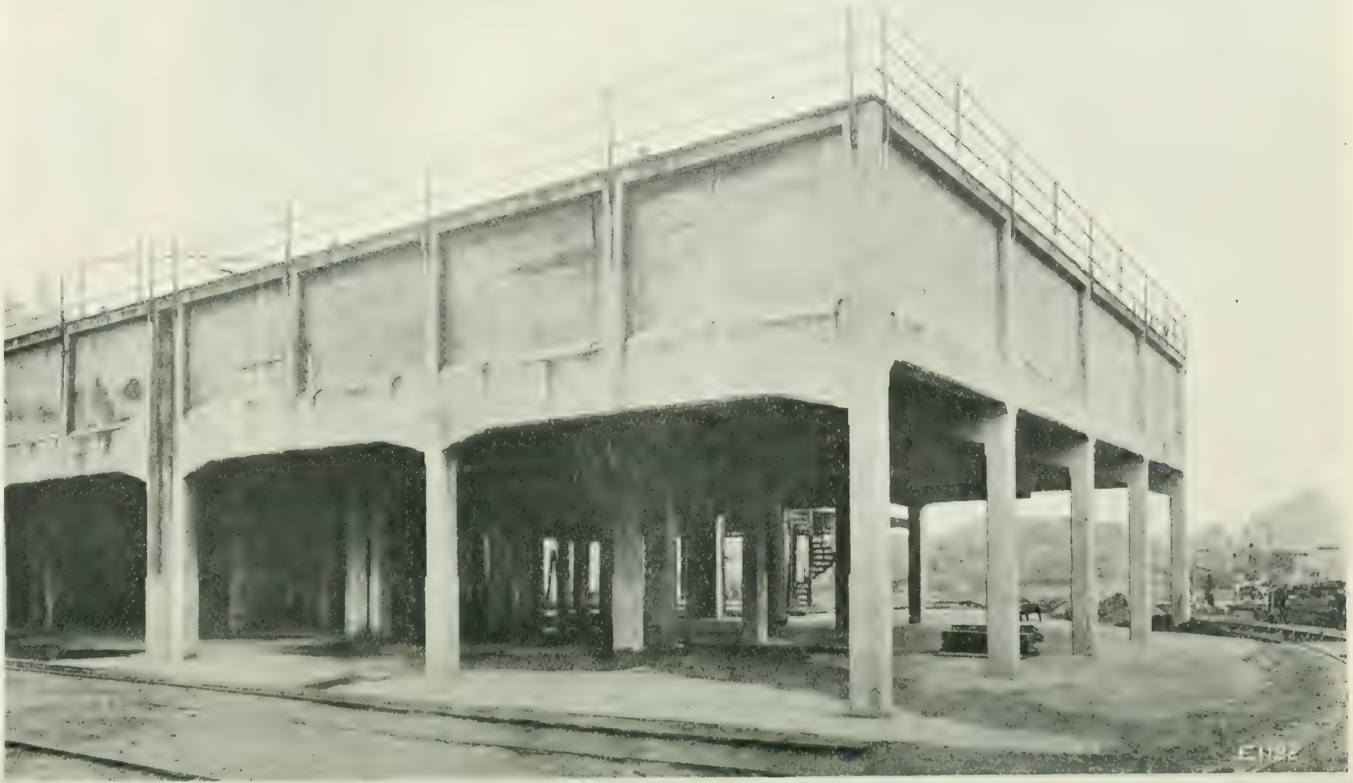


[Frontispiece

General Elevation of Reinforced Concrete Purifiers for the Tottenham Gas Works.

(For Description see p. 613.)

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XIII., No. 12. LONDON, DECEMBER, 1918.

EDITORIAL NOTES.

HOUSING PROBLEM.

INTRODUCTION.

THE cessation of hostilities and the dawn of a new era of peace have naturally caused us to turn to the consideration of some of the immense problems of reconstruction, and among these problems that of providing the necessary housing accommodation is one of the most important. The shortage of small houses and cottages is enormous, and it is estimated that half a million new dwellings are required immediately in addition to the annual supply of about one hundred thousand, and thus considerable organisation in labour and the supply of materials will be necessary if the task is to be accomplished with any measure of success. The question of cost, which in normal times must necessarily affect the erection of small dwellings to a large extent, cannot entirely dictate the conditions of lay-out and construction under the pressing needs of the problem, as the question has become a national one, and it is the duty of the State not only to foster the building industry with legal assistance, but also to support it financially as circumstances may require. A very important report has been issued by the Committee which was appointed by the Local Government Board and the Secretary for Scotland, to consider the various questions of building construction in connection with the provision of dwellings for the working classes and the methods of securing economy and dispatch in the provision of such dwellings, and some of the recommendations contained in this report are worthy of consideration.

The names of the members of the Committee who sign the report will give considerable weight to the various suggestions put forward, and as two architects of artistic eminence were included the question of the general appearance of the worker's home has not been overlooked. The amount of work which was accomplished and the number of suggestions that were made can be gathered when it is stated that the report covers nearly one hundred pages, and therefore it is only possible in these notes to touch briefly on some of the most important matters.

HOUSING DEPARTMENT.

In order to deal effectively with the general matters which of necessity must arise in various localities the Committee recommend that a strong Housing Department, with an experienced and capable Chief Commissioner, should be created, both at the Local Government Board for England and Wales and at the Local Government Board for Scotland. The country would then be divided into districts and local commissioners be appointed who would work under the central control but have executive powers vested in them to deal with the problem effectively and with dispatch. These commissioners should be men with technical knowledge and experience in housing, acquainted with modern methods of town planning and development and imbued with a real live interest in their work. Their functions should be to encourage and assist local house building and primarily to secure effective co-ordination between the various local authorities, public utility societies, and other forms of private enterprise, so that the requirements of each district may be fully met. In these commissioners might be vested considerable discretionary powers with respect to building bye-laws, so that modifications and relaxations might be made to suit the requirements of individual schemes and avoid the expenditure of unnecessary money while at the same time safeguarding the public from doubtful experiments.

This suggestion appears to be quite feasible and should materially assist in the speeding up of the execution of schemes, provided the powers vested in the commissioners is a real one and that they are not hampered by too many official instructions as to routine and the usual delay which occurs in obtaining co-operation or sanction from Government Departments is avoided. The party responsible for a scheme will require some relaxation from the bye-laws in practically every instance, and if he can get into personal touch with the person who is authorised to allow such relaxation a great deal of benefit will result as regards saving of time, but great care must be exercised that such personal intercourse can result in something decisive and that it is not merely the prelude to the filling in of numerous forms and applications accompanied by delays in obtaining some kind of official sanction. If the commissioners are men of the right calibre and real power is given to them the scheme would then be of great assistance.

SUPPLY OF MATERIALS.

A Special Committee has been set up by the Ministry of Reconstruction to deal with this question, and consequently the Local Government Board Committee only touches upon the subject generally and in so far as it affects the need of looking for alternative methods of construction. In the recommendations it is stated that the release of the industries of the country from State control at the earliest possible moment is the object to be aimed at, but there must inevitably be a transitional period during which this control can only be partially relaxed, otherwise, certainly in the case of building materials, there will be, in some directions, a shortage of supply and, as a result of competition for available supplies, rapidly rising prices. The supply of timber will probably, for a period after the war, be still under the supervision of the Timber Controller and subject to fixed maximum prices. With respect to bricks, which play an important part in house building, the most effective policy for regulating prices is stimulus of production, which also applies to slates, cement, and other materials. It is hoped that the Government will be able to arrange for an early supply of essential labour on demobilisation and of the necessary fuel so that the work of production may be undertaken without delay. In any priority schemes that are set up by the Government for controlling the supply of building materials a privileged position must be given to housing schemes, and here again the proposed Housing Department could render valuable assistance in the determination of the terms upon which priority certificates should be granted in the various districts. It is perfectly clear that there will be a great scarcity of all classes of materials, and it will be necessary to adopt as wide a variation as possible in the methods adopted throughout the country to prevent an excessive call upon any one material. But the shortage is more marked in some materials than in others, as will be shown hereafter in the notes on construction, and it is to the necessity of finding substitutes for these that attention should be turned.

BYE-LAWS.

It is interesting to note that in the report it is stated that the evidence received tends to show that bye-laws and other regulations in the past have hampered progress in new forms of construction ; that it is partly due to their influence that this country is behind others in the practice of concrete and reinforced concrete construction, and they have needlessly added to the cost of house building and estate development.

This point has been repeatedly raised during recent years, and we have advocated a revision of bye-laws which are obsolete and a barrier to the development of scientific construction. In many bye-laws there is a clause which states that the thickness of a concrete wall must be at least one-third more than the specified brickness of a brick wall of the same height, and this in spite of the many examples of good concrete construction which have been in existence for years. The building industry is a progressive one, and the regulations which control it must be framed to provide for new methods and materials and not be such that a possible improvement is stifled and discouraged and so placed at a disadvantage because the authorities had not thought of it at the time of framing such regulations.

LAY-OUT AND DEVELOPMENT.

Some extensive notes are given on the lay-out and development of sites, the accommodation required and economy in its provision, and various other matters, all more or less important, are dealt with and numerous plans and diagrams are given to illustrate the recommendations of the Committee. These notes should, no doubt, be of service, but there is nothing very new in the points raised, and their chief value will probably be due to the fact that they are supported by a certain amount of authority and they are comprehensive. The planning of a cottage is a fascinating subject, but after many variations, apparent "brain-waves" and much consideration, the designer will always come back to the starting-point fully convinced that the most simple and straightforward plan is the best and the cheapest, and that the problem of the cheap dwelling will be solved in the construction and finishing rather than in the planning. The recent competitions that have been held will prove that any radical economy cannot be effected without advantage being taken of new and efficient forms of construction.

ECONOMY IN CONSTRUCTION.

This section is probably the most valuable in the whole report, and it will also be the most interesting to our readers, and we consequently propose to publish the important items in this and subsequent issues in addition to making a few comments in these notes.

It is stated at the outset that, while science and skill have been devoted in ever-increasing measure to the development of industrial processes, no such attention was paid to house building. This, of course, is easily explained when it is remembered that science and skill applied to improved methods of construction always had to face the obsolete bye-laws above referred to, and consequently no advantage was likely to accrue to the builder who attempted to economise, even when improving a method, if by so doing he was infringing a regulation which had to be enforced although it was not really applicable in the spirit. Only those who have been faced with the necessity of complying with the letter of the Act can fully realise how thoroughly science has been discouraged in the past, and thus construction has been compelled to follow the old-fashioned methods.

We are glad to see that a number of investigations are being undertaken, with the assistance of the Department of Scientific and Industrial Research, to determine the durability and other qualities of some of the materials and methods recommended by witnesses. It is proposed to issue a subsequent report when these investigations are completed, and these will be awaited with interest.

The two main items that were dealt with were: (1) The consideration of possible substitutes generally or locally advantageous in place of bricks or stone for walling in connection with cottages, particularly the question of the use of concrete for such purpose, and (2) the finding of substitutes for the various uses of timber in cottage construction. In connection with the first item it is stated that there cannot be any sensational amount of saving by the use of brick or concrete as compared with one another in those districts where bricks are made and a good aggregate is also available, but where bricks are not locally produced and where gravel and sand are at hand then concrete should prove substantially less costly than brick. This conclusion will undoubtedly be in accordance with the views of those who have had experience in connection with the subject, but the question of cost is not the only one that must be considered. It is estimated that the erection of 300,000 cottages would require over 5,400,000,000 bricks, and with the brickyards in their present condition it will be realised that the demand cannot be met without a delay that will be serious, and thus it is absolutely essential to provide some other material for at least a large proportion of the work. This other material is concrete, and generally speaking the use of this in the form of blocks built to give a cavity wall will prove the only satisfactory solution to the problem. Great stress is laid on the fact that greater skill is required in the supervision of concrete work and that workmen and masters are more experienced in brick construction. These facts should not be a serious bar to the extensive use of concrete for walling, as there are numerous engineers and architects throughout the country who are competent to supervise the work, and the simplicity of concrete work of this nature would enable the workers to become proficient in a very short time under able supervision. The four objections to concrete walling which are put forward can hardly be substantiated, as they relate to a hold for fixing and chases, which would be provided during execution, and the question of repairs and alterations, which should not be necessary if the work is properly planned and organised.

With regard to substitutes for timber the suggestions are: (1) Concrete in various forms, (2) hollow brick or terra-cotta, and (3) iron or steel. All these three will probably enter very largely into cottage construction in the near future, but here again it will be found that concrete, either plain or reinforced, will go far to solve the difficulty created by the timber shortage. In order to reduce the amount of shuttering required, the system of pre-cast units must be properly developed and standardised, and if this is done very little timber need be used. If timber has to be supplied for the work which is usually executed in this material by the carpenter and joiner, several thousand standards will be necessary, and such a demand cannot be met under the existing circumstances. Concrete can be profitably employed in floor and roof construction, and it has been adopted for door and window frames and similar features with considerable success. We do not wish to imply that concrete is the only material to be used or that it is the best for all and every purpose, but it will undoubtedly prove to be a greater factor in meeting the needs of the housing problem than any other, and as such it is advisable to encourage the intelligent use of the material and not produce a number of small and fanciful objections which are usually due to the conservatism of the English people.

Generally, the Committee, so ably presided over by Sir Tudor Walters, is to be congratulated on the way it has handled a very difficult subject, and great credit is due to the Committee's able secretary, Mr. Leonard, for his indefatigable labours. A weak spot in the enquiry from this journal's point of view is, of course, the absence of sufficient evidence from professional men of standing on the possibilities of, and the experience obtained with, concrete. How came it, may we ask, that the Concrete Institute was not represented in the presentation of considered evidence? Where, too, were the cement makers? If not invited to give evidence, evidence could surely have been volunteered! With suitable evidence before them, we could not have had some of the weak expressions of opinion regarding concrete, which detract from the value of the Committee's report. We would probably also not have found the Committee using the term *ferro-concrete* where "reinforced concrete" is the correct general term. Nor would the term *fireproof* have been used for brick and tile floors of moderate fire resistance where "fire-resisting" was the term agreed upon by the representatives of all the Government departments as far back as 1903.

If the Committee continues its work, it should be strengthened by the presence of one or more architects and surveyors who are authorities on building construction and materials although they may not necessarily be great artists.

THE COMMITTEE'S CONCLUSIONS REGARDING CONCRETE AS A MATERIAL FOR COTTAGES.

As stated above, we reproduce on p. 634 part of the section of the Report dealing with construction, but in order to give our readers, briefly, the views formulated by the Committee regarding concrete, we reproduce, for what they are worth, the somewhat half-hearted "Conclusions" regarding that material, which read as follows :—

Concrete.

104. In reference to the use of concrete for walls in house building, we have arrived at the following conclusions :—(204-219.)

(i) That where bricks are plentiful there is not likely to be any great saving by the use of concrete.

(ii) That in localities where bricks are not produced and where a suitable aggregate is available, concrete, if adopted on a sufficient scale, is likely to prove an economical building material.

(iii) That, provided proper precautions are taken, concrete affords a suitable and durable material for the construction of houses.

(iv) That the chief dangers arise from the imperfect grading or mixing of the materials, the use of materials containing sulphur, lime, salt, or other impurities, the use of blocks or slabs which have not been allowed sufficient time to mature, and the use for the inner surface of mixtures too impervious and too good conductors of heat resulting in condensation or sweating.

(v) That further investigation into this matter is required to determine the qualities of different aggregates and of concrete made from them, especially in reference to the safe use of such aggregates.

(vi) That in whatever form concrete slabs are used, it is important that ample time should be allowed for them to mature before they are built into the walls.

(vii) That although many alternative methods have been used with success, and some promise to prove increasingly valuable with further development and experience, the simplest and most reliable method of using concrete for the external walls of dwellings is in the form of slabs built up as complete cavity walls, the outside slabs being weather-proof, the inside slabs being sufficiently porous and non-conducting of heat to discourage condensation.

(viii) That the inside slabs of cavity walls, having to carry the main weight of floors and, being often composed of concrete of less strength than the outside slabs, should, to give adequate strength, be of greater thickness than is required for the outer slabs, and that a thickness of 4 in. is sufficient for two-storey buildings pending further investigation.

(ix) That where the external slabs are not of themselves sufficiently weather-proof the wall should be rendered in cement or coated with rough-cast.

(x) That the best method of securing weather-proof concrete is to use good impervious aggregate properly graded and thoroughly mixed ; that some of the specifics for waterproofing concrete may be found useful to correct failures, but that it is better to trust to good materials and skilled handling.

105. In districts where good aggregate is relatively more available than brick or economical building stone, concrete construction should be considered as an alternative. (219.)

106. Encouragement should be given to a few experiments to test the more promising methods of using concrete on a sufficiently large scale to prove their economic value as well as their efficiency. (250.)

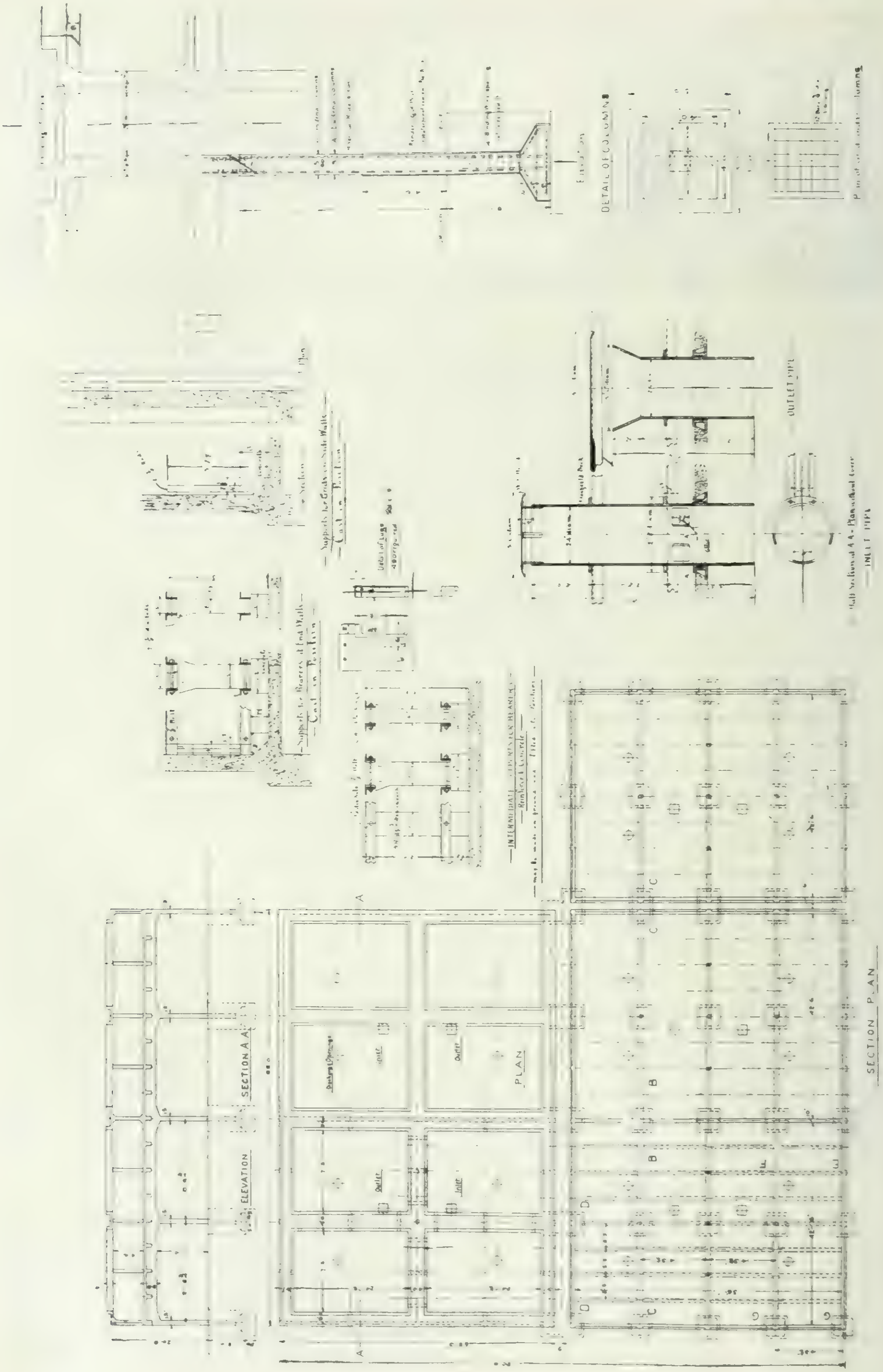
REINFORCED CONCRETE PURIFIERS.

The following short description of some concrete purifiers erected by the Tottenham Gas Works call for special attention, inasmuch as they are the first purifiers that have been erected above-ground in reinforced concrete. For our particulars and illustrations we are indebted to the courtesy of Mr. A. E. Broadberry, engineer and manager to the Tottenham Gas Works.—ED.

THE Tottenham District Light, Heat & Power Co. have recently erected at their gas works, Willoughby Lane, Tottenham, a set of purifiers constructed of reinforced concrete. As the use of this material for overhead purifiers is an entirely new departure, a description of them, with the accompanying illustrations, will doubtless be of interest.

For the benefit of those who are not familiar with the process of gas manufacture, it should be explained that after the gas has been evolved from the coal by heating it in closed retorts it has to be freed from tarry vapour, ammonia, etc., by cooling and washing, after which the impurity known as sulphuretted hydrogen (H_2S) has to be removed very thoroughly so that the clean gas is quite free from it. At present the universal practice is to pass the gas through several layers of hydrated ferric oxide which, when found in a natural state, is known as "bog ore." This material becomes very dense and hard in use—particularly the kind artificially prepared—and it will be realised that very large containers, known as purifiers, have to be employed to deal with the large volumes of gas made, that is, unless high pressure is employed, which for many reasons is undesirable. It has hitherto been the practice to construct these purifiers of cast-iron plates, either on the ground or at a height of 8 or 10 ft. above ground, for convenience in discharging the "oxide" when it has ceased to be active. For small works they are usually in or on the ground, but in larger works they are almost universally erected overhead on a framework of rolled steel joists carried on cast-iron columns. In former days, when purifiers were smaller, the covers were made all in one piece of thin steel or W.I. plate on a framework of angles and tees, and the gas-tight joint was made by means of a water seal. Even with comparatively small covers very strong gantrys had to be used to lift these covers and traverse them out of the way when filling and emptying the purifiers.

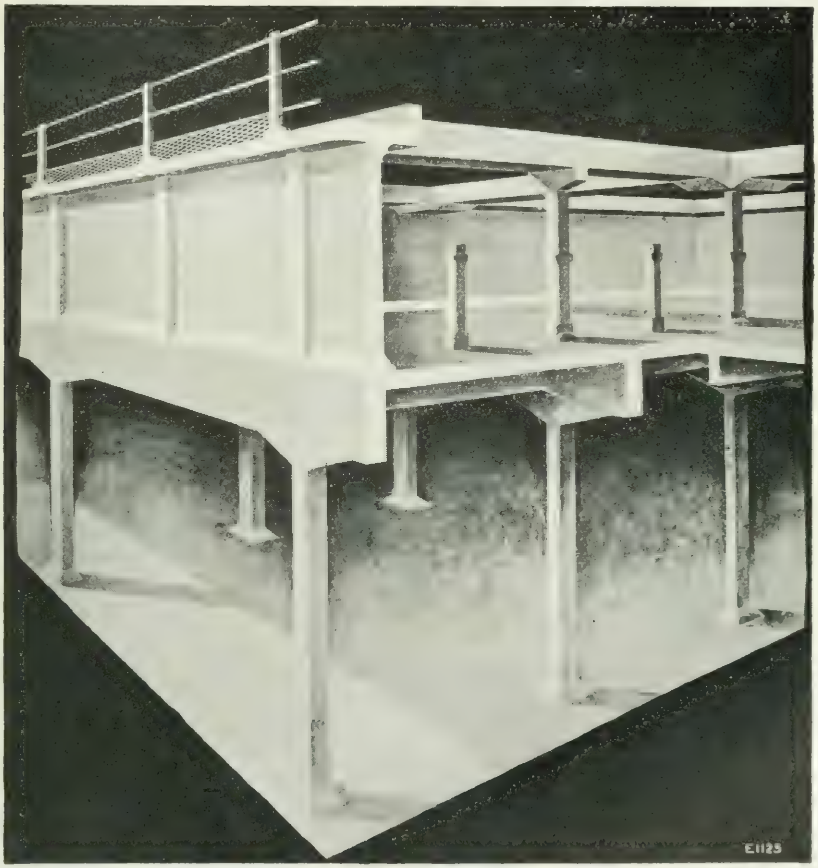
For many years past, however, it has been the practice to construct a narrow deck round the top of the purifier and to bolt the cover—reduced in size by the width of the deck—directly to the cast iron with a rubber joint in between. The practice has been extended in the case of large purifiers to the construction of gangways across the purifier, so dividing the top into two or four parts, as by so doing the covers could be reduced to more manageable proportions and the



Plans, Sections, Elevations.

Reinforced Concrete Purifiers for the Tottenham Gas Works.

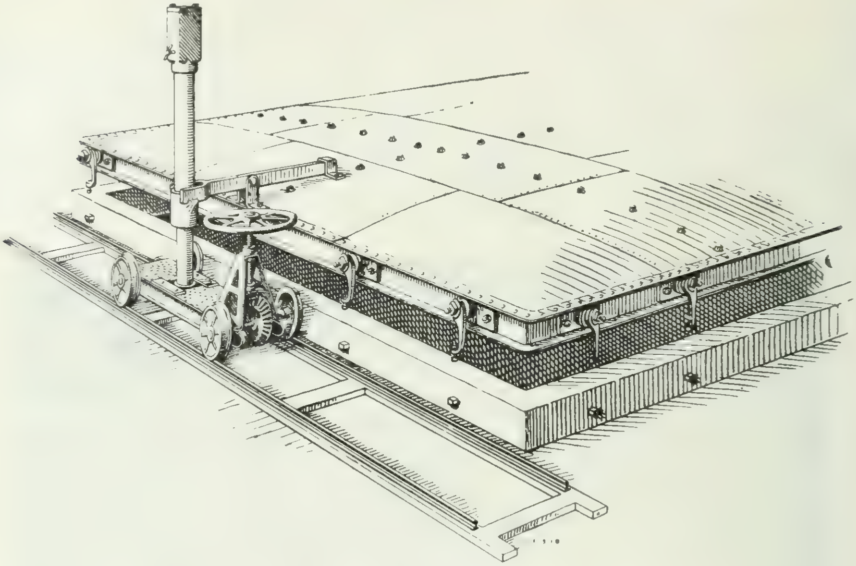
use of heavy goliath cranes avoided. With these particulars in mind we will now turn to the purifiers under consideration. The quantity of gas to be dealt with was five million cu. ft. in twenty-four hours, and the site lent itself to the erection of five purifiers each 56 ft. 1 in. by 42 ft. 6 in. inside. Four of these form the main set ; the gas passes through each in succession and the remaining one is used as a catch box—*i.e.*, a final precaution against any possible failure of the routine set. They are 6 ft. deep inside and they have to sustain a possible gas pressure equal to 4 ft. of water, in addition to a distributed load of about 300 tons of oxide, with the steel angles and wood grids required to support it. This represents a very heavy load on the main beams, and it will also be observed that the sides have to resist the full pressure of gas from top to bottom, and the decks and gangways have to resist an upward pressure of the same amount, exerted on them and the covers by the gas.



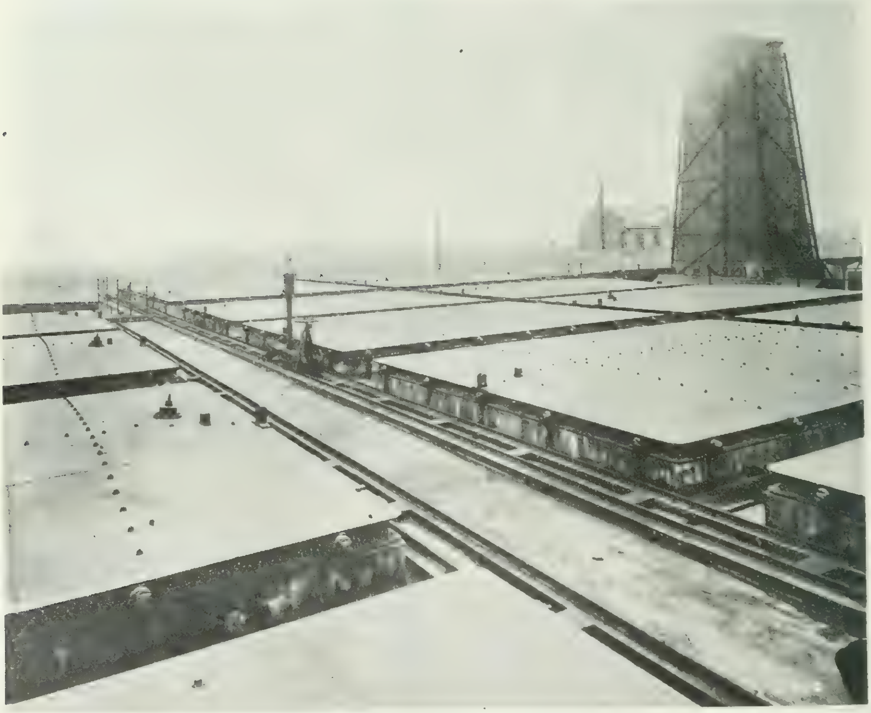
Sketch illustrating method of construction.

Reinforced Concrete Purifiers for the Tottenham Gas Works

To minimise the effect of temperature—as the oxide sometimes heats up—the main series of four was divided into two pairs, with a space between them



PURIFIER COVER RAISED ON HYDRAULIC TRAVERSING JACK



Purifier Covers.

REINFORCED CONCRETE PURIFIERS FOR THE TOTTENHAM GAS WORKS.

wide enough for an elevator or conveyor. The fifth, or catch box, was built as a separate structure altogether; this arrangement is shown on the plan and elevation. The main beams, 33 in. deep, are divided into four spans and are carried on columns 15 in. square for the interior and 13 in. square for the exterior. These columns have reinforced feet resting on mass concrete foundations with a steel mat to distribute the pressure. The secondary beams are 21 in. deep, the floor slab 5 in. thick, the sides 7 in. thick, and the decks and gangways 6 in. thick. It is very important to keep the interior of purifiers as free from obstructions as possible, and in this case only five pillars, 10 in. square, are used to support the gangways. These pillars form, of course, ties between the floor and top when the purifiers are closed and under pressure. Special provision was made for anchoring gangways and pillars. The mixture used was the usual one of 4 : 2 : 1, but for the columns a slightly richer mixture was used, as they were made horizontally and elevated into position when set. To render the concrete gas-tight the purifiers were treated on the inside with "Ironite." Special provision was made to keep the weight of the massive 24 in. diameter pipes, forming the gas mains, from coming on to the floor of the purifiers. There are also four discharge outlets provided for emptying each purifier. The covers are secured to lugs let into the concrete by a special form of eccentric fastening invented by the company's engineer, Mr. A. E. Broadberry. When the vessels were completed they were tested first with 4 ft. of water, which gave as great a load as the columns would bear although it did not give the maximum load on the beams. The deflection of the latter only amounted to $\frac{3}{100}$ths of an inch. After this test, arrangements were made to flood the decks and gangways with 3 in.

Elevation of the Apparatus Building constructed with Concrete Blocks made on "Winget" Machines.

of water ; the covers were put on and an air pressure of 24 in. of water was applied. In one or two places a few air bubbles were observed, but further treatment with a mixture of " Ironite " and cement immediately remedied these defects. The purifiers have been in use for a year, no defects have developed, and they are considered in every respect satisfactory, particularly as their cost was barely half of what it would have been if they had been made of cast-iron on a steel platform.

They were constructed by Messrs. Walter Jones and Sons to the designs of the company's engineer and manager, Mr. A. E. Broadberry, M.Inst.C.E., assisted by Mr. J. Fisher, Assoc.M.Inst.C.E., the assistant engineer of the company.

Reinforced concrete is now being extensively used in gas works, both for buildings and special constructions. For instance, at the Tottenham Works the foundations for vertical retort benches, coke loading stages, tar and liquor tanks, cyanide purifiers, coal hoppers, etc., have been constructed of this material, and although not strictly reinforced concrete, the apparatus buildings, of which an illustration is given, are constructed of concrete blocks on a steel framework.

DETAIL DESIGN IN REINFORCED CONCRETE.

VII.

By

EWART S. ANDREWS, B.Sc.Eng., M.C.I.

The last article of this series appeared in our issue of August, 1918.—ED.

DESIGN OF RETAINING WALLS *(concluded)*.

Counterforted Walls; General Principles of Design.—In the counterforted type of wall (*Fig.* 26), counterforts or webs are provided at intervals apart which connect the wall slabs to the base slabs and act as supports for the slabs. The wall slab may be designed as a series of continuous horizontal beams of span equal to the distance l apart of the counterforts, the loads on different strips being taken from the pressure triangle $a\ b\ c$.

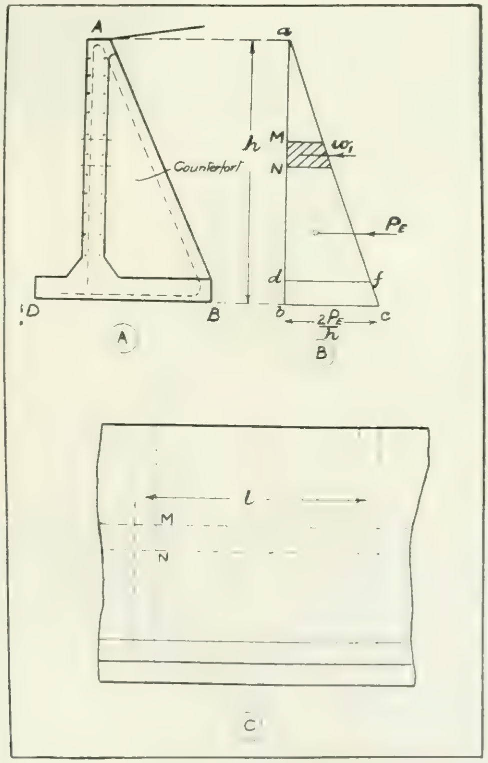


FIG. 26.

If, for instance, we wish to find the horizontal reinforcement of the strip *MN*, we find the weight w_1 per foot length of the beam by calculating the area of the corresponding shaded portion of the pressure triangle. We then take by regulation **35** a bending moment at supports and centre of span equal to $\pm\frac{w_1 l^2}{10}$; the necessary horizontal reinforcement is then found in the manner previously described, due allowance being made for the reverse bending moment. For interior spans, the regulations would allow us to design the centre portion of the span for a bending moment equal to $\frac{w_1 l^2}{12}$, but this is not generally done in retaining-wall design.

The counterfort is designed by regarding it as the rib of an inverted T beam, the section at the base being made strong enough to carry the whole bending moment at the base.

$$i.e., B = l \times \text{area } adf \times \frac{ad}{3}$$

The front base slab is designed as a cantilever the load upon which is obtained from the resultant pressure diagram for the base, as in the case of the cantilever wall.

The back base slab is designed as a continuous horizontal beam of span *l*, the load upon which is given by the resultant pressure diagram for the base.

These points are best illustrated by means of a numerical example.

Numerical Example.—*A counterforted retaining wall of total depth* 25 *ft. is required to support clay soil weighing* 110 *lb. per cu. ft., the angle of repose being* 30°, *and the earth being surcharged* 20°. *Counterforts are to be* 10 *ft. apart, and the base slab* 2 *ft. thick.*

We will first determine the pressure triangle *a b c*.

From *Fig.* 23 we see that
$$\begin{aligned} P_E &= \cdot 22\, w_e h^2 \\ &= \cdot 22 \times 115 \times 25^2 \\ &= 15{,}800 \text{ lb. per ft.} \\ &= 15{\cdot}8 \text{ kips per ft.} \end{aligned}$$

$$\therefore \text{ base } bc \text{ of triangle} = \frac{P_E \times 2}{h} = \frac{15{,}800 \times 2}{25} = 1{,}260 \text{ lb. per sq. ft.}$$

At bottom of wall slab, weight per foot run
$$\begin{aligned} &= g\,h \\ &= \frac{22}{25} \times 1{,}260 \\ &= 1{,}000 \text{ lb. approx.} \\ &= 1 \text{ kip.} \end{aligned}$$

$$\therefore B = \frac{1 \times 10 \times 120}{10} = 120 \text{ kip-inches.}$$

From the diagram of *Fig.* 2 we see that the minimum effective depth for the economical section is 10½ in., so that we will take an overall depth of 12 in.

We will next proceed to determine the necessary width of base from the standpoint of safe pressure upon the soil; the latter we will take as being ordinary clay, so that in accordance with regulation **136** the pressure per sq. ft. on the soil may not exceed 2 tons per sq. ft. (*i.e.*, 4·48 kips per sq. ft.).

Let us first assume the dimensions given in *Fig.* 28.

Our earth weighs ·110 kips per sq. ft., and the reinforced concrete ·144 kips per sq. ft. We then have:

Weight of wall $= \cdot 144 \times 23 \times 1 = 3{\cdot}31$
,, ,, base $= \cdot 144 \times 12 \times 2 = 3{\cdot}46$
,, ,, filling $= \cdot 110 \times 8 \times 24{\cdot}5 = 21{\cdot}55$

Total $= W = 28{\cdot}32$ kips

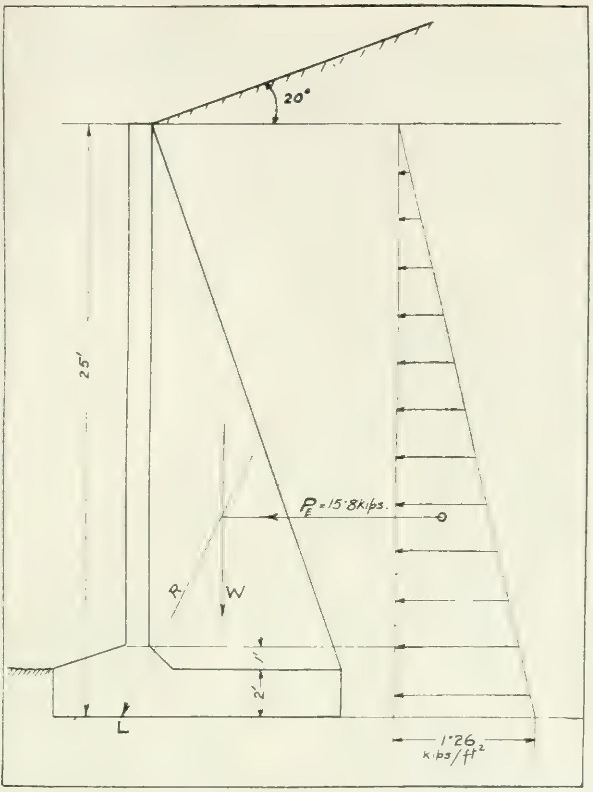


FIG. 27.

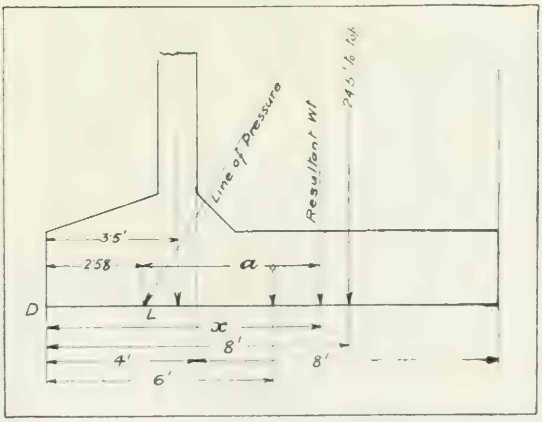


FIG. 28.

Moments about edge *D*—

$$\begin{aligned} \text{Wall} &= 3{\cdot}31 \times 3{\cdot}5 = 11{\cdot}6 \\ \text{Base} &= 3{\cdot}46 \times 6 \phantom{{\cdot}5} = 20{\cdot}8 \\ \text{Filling} &= 21{\cdot}55 \times 8 \phantom{{\cdot}5} = 172{\cdot}4 \\ \text{Total moment} &= 204{\cdot}8 \end{aligned}$$

$\therefore$ Distance x of resultant weight from edge $D = \frac{204\cdot8}{28\cdot32} = 7\cdot23$ ft. approx.

Distance a of load point L from line of action of weight

$$= \frac{8\cdot33 \times 15\cdot8}{28\cdot32} = 4\cdot65 \text{ ft.}$$

$\therefore$ Distance $DL = 7\cdot23 - 4\cdot65 = 2\cdot58$ ft.

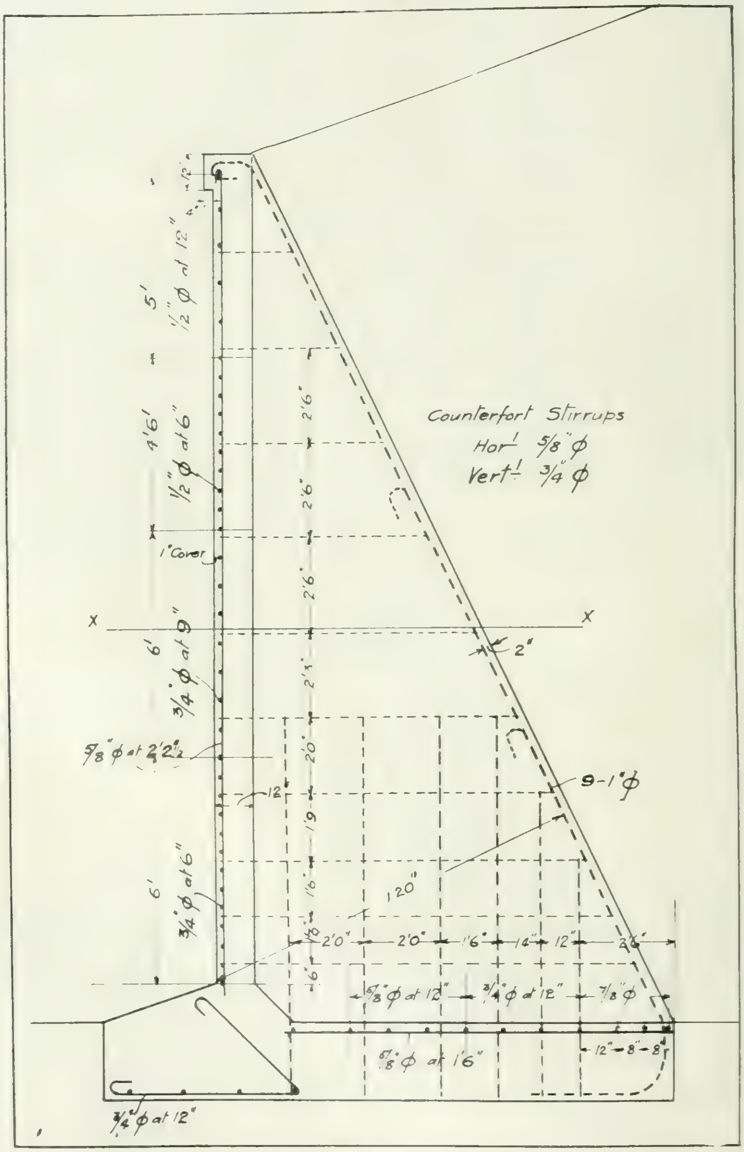


FIG. 29

The load point in this case, therefore, comes outside the middle third.

$$\therefore \text{ Max. pressure on soil} = \frac{28\cdot32 \times 2}{3 \times 2\cdot58} = 7\cdot3 \text{ kips per sq. ft.}$$

This is too much, so that we must extend the base.

Try extending the dimension 8 ft. to 10 ft., this increases the weight by an amount approximately equal to $(26{\cdot}5 \times 2 \times {\cdot}110 + {\cdot}144 \times 4) = 6{\cdot}41$ kips and the moment by $6{\cdot}41 \times 13 = 83{\cdot}3$.

$$\therefore x = \frac{204{\cdot}8 - 83{\cdot}3}{28{\cdot}32 + 6{\cdot}41} = \frac{288{\cdot}1}{34{\cdot}73} = 8{\cdot}30 \text{ ft.}$$

$$a = \frac{8{\cdot}33 \times 15{\cdot}8}{34{\cdot}73} = 3{\cdot}79 \text{ ft.}$$

$$\therefore DL = 8{\cdot}30 - 3{\cdot}79 = 4{\cdot}51 \text{ ft.}$$

$$\therefore \text{Max. pressure on soil} = \frac{34{\cdot}73 \times 2}{3 \times 4{\cdot}51} = 5{\cdot}13 \text{ kips per sq. ft.}$$

This is still too high, so that we will extend the base 1 ft. further, as shown in *Fig.* 29.

This increases the weight by an amount approximately equal to $(27 \times {\cdot}110 + {\cdot}144 \times 2) = 3{\cdot}26$ and the moment by $3{\cdot}26 \times 14{\cdot}5 = 47{\cdot}3$.

$$\therefore x = \frac{288{\cdot}1 - 47{\cdot}3}{34{\cdot}73 + 3{\cdot}26} = \frac{336{\cdot}4}{38{\cdot}0} = 9{\cdot}1 \text{ ft.}$$

$$a = \frac{8{\cdot}33 \times 15{\cdot}8}{38{\cdot}0} = 3{\cdot}5 \text{ ft.}$$

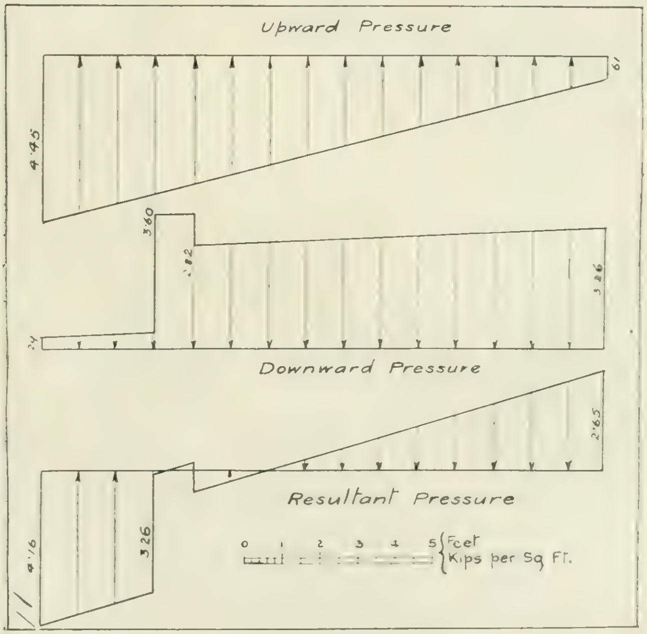


FIG. 30.

$$\therefore DL = 9{\cdot}1 - 3{\cdot}5 = 5{\cdot}6 \text{ ft.}$$

$\therefore$ Eccentricity of load from centre of base $= 7{\cdot}5 - 5{\cdot}6$ ft. $= 1{\cdot}9$ ft.

$$\therefore \text{Max. pressure on soil} = \frac{38{\cdot}0}{15}\left(1 + \frac{6 \times 1{\cdot}9}{15}\right)$$

$$= 2{\cdot}53 \times 1{\cdot}76 = 4{\cdot}45 \textit{ kips per sq. ft.}$$

Min. pressure on soil $= 2{\cdot}53\ (1 - {\cdot}76) = {\cdot}61$ *kips per sq. ft.*

These pressures are within the limits allowed, and so the dimensions which will be adopted are 3 ft. projection at front and 11 ft. at back.

In these calculations we make no allowance for the additional weight of the counterfort over its equivalent volume of soil; the effect of this upon the results will be negligible.

We are now in a position to draw the resultant pressure diagram for the base as shown in *Fig.* 30.

Sliding Resistance of Wall.—Taking $\tan \varphi' = \cdot 5$ for dry clay, we have the sliding resistance $= W \tan \varphi' = 38 \cdot 0 \times \cdot 5 = 19$ kips; this is greater than the maximum earth pressure, which we have shown to be equal to 15·8 kips.

It might be urged that since $\tan \varphi' = \cdot 33$ for moist clay we ought to err on the safe side and take this value because it is difficult in practice to be sure that the clay will not become wet; in reply to this we point out that, if the clay is moist, the angle of repose will become much more than 30°, which we have assumed, and this means that the earth pressure will become much less, so that the wall will still be safe against sliding even if the clay becomes damp.

Detail Design of Reinforcement.

Wall Slab.—We have shown already that the maximum bending moment in the wall slab is 120 kip-inches, and we have decided to adopt an effective depth of $10\frac{1}{2}$ in.; we will turn to the diagram of *Fig.* 2 and find the spacing required for $\frac{3}{4}''$ round bars. To do this we run down vertically from the point where the $10\frac{1}{2}''$ line cuts the top until we meet the dotted line marked $\frac{3}{4}'' \varphi$; we then run out horizontally on to the right-hand scale and note that the spacing required is 6·5 in. We will adopt 6 in.; this may be increased to 9 in. when the bending moment is reduced to 87 kip-inches, and since the B.M. is proportional to the earth pressure, and that decreases uniformly to zero at the top, we may increase the pitch of the $\frac{3}{4}'' \varphi$ bars to 9 in. at a depth of $\frac{87}{120} \times 23 = 16 \cdot 7$ ft. from the top—*i.e.*, we will have twelve rows of $\frac{3}{4}'' \varphi$ bars at 6 in. apart, and then space them at 9 in.

We will continue this until $\frac{1}{2}'' \varphi$ bars can be used at 6 in. apart; running in from the 6″ line on the right of *Fig.* 2 until we meet the dotted $\frac{1}{2}'' \varphi$ line, and then dropping vertically to the $10\frac{1}{2}''$ line and running out horizontally to the left, we read 58 kip-inches, so that we may come down to $\frac{1}{2}'' \varphi$ bars at 6 in. about half-way up, as shown in *Fig.* 29, and then increase to 12 in., as shown, maintaining this pitch to the top. In order to provide for the reverse bending moments at the supports we will bend up as shown in *Fig.* 31; this arrangement enables us to use all bars of the same shape, thus assisting considerably in the construction.

Distributing bars have to be provided in accordance with regulation **78**; they must not be further apart than 18 in., and must have an aggregate cross-sectional area of at least ·08 per cent. of the effective cross-sectional area of the slab, or the diameter of each such bar shall be at least one-sixteenth of the effective depth of the slab, and the pitch four times the effective depth.

If we take them at 18 in. apart, the area of each must be $= \frac{\cdot 08 \times 18 \times 10 \cdot 5}{100} = \cdot 151$ sq. in.; a $\frac{1}{2}'' \varphi$ bar will have an area of ·196 and would do.

Taking the second alternative, least diameter of bar required $= \frac{10 \cdot 5}{16}$—say $\frac{5}{8}$ in.; although the regulations would allow us to increase the pitch up to 42 in., this is more than is desirable; we will adopt $\frac{5}{8}$ bars at 2 ft. 6 in. pitch.

SHEAR.—The maximum shearing force on one of the horizontal beams 1 ft. wide into which we consider the wall slab as divided is $1 \times 5 = 5$ kips.

Taking the lever arm as $\cdot 88\ d$ we have $a = \cdot 88 \times 10 \cdot 5 = 9 \cdot 2$ in.

$$\therefore \text{Shear stress in lb. per sq. in.} = \frac{5{,}000}{12 \times 9 \cdot 2} = 45 \cdot 3$$

This is less than is allowed on the concrete alone, so no special shear reinforcement is necessary

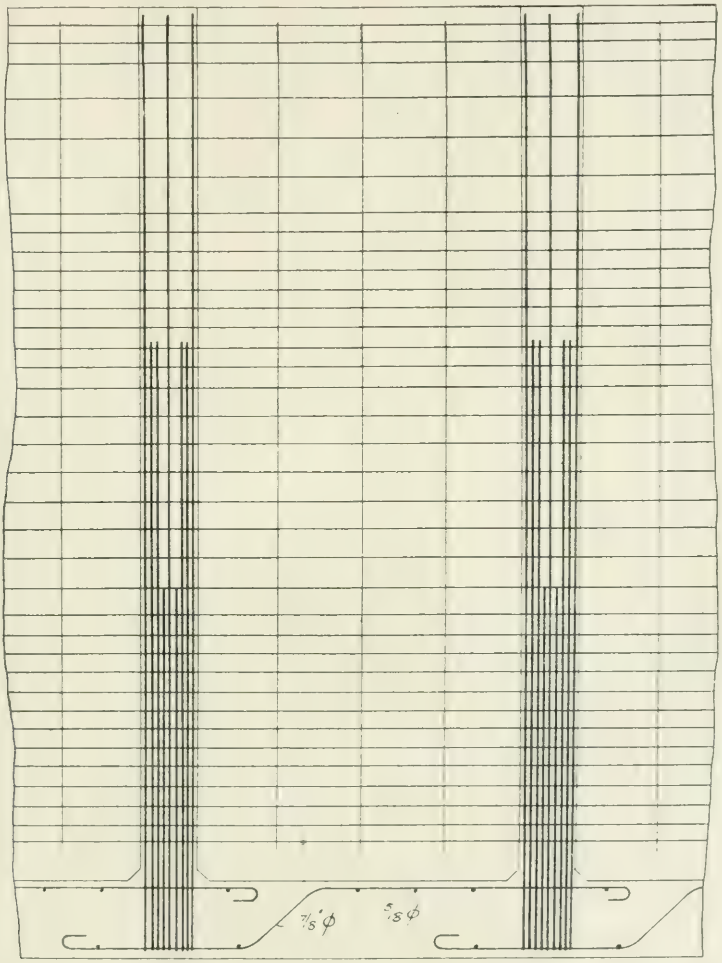


Fig. 31.

Front Base Slab.—This has to be designed as a cantilever ; taking the pressure given by *Fig.* 30, we have for 1 ft. length of wall

$$\text{Max B.M.} = \frac{(4 \cdot 16 + 3 \cdot 20)}{2} \times 3 \times 18 \text{ kip-in}$$

$$= B = 200 \text{ kip-in. approx.}$$

Taking the effective depth d as 34 in. and the lever arm a as $= \cdot 9\ d$, we have :

$$\text{Area of steel required per foot} = \frac{200}{16 \times \cdot 9 \times 34} = \cdot 41 \text{ sq. in}$$

We will adopt $\frac{3}{4}''$ φ bars 12 in. apart.

$$\text{The maximum shearing force} = \frac{(4{\cdot}16 \times 3{\cdot}26)}{2} \times 3 = 11{\cdot}1 \text{ kips.}$$

$$\therefore \text{ Shear stress per sq. in.} = \frac{11{\cdot}1 \times 1{,}000}{12 \times {\cdot}9 \times 34} = 30{\cdot}2 \text{ lb. per sq. in.}$$

This is less than is allowed by the regulations, but we think it desirable to bend up the bars as shown in *Fig.* 29.

Back Base Slab.—The downward pressure per sq. ft. varies as shown in *Fig.* 30. Taking the first foot from the extreme end, we have a mean pressure of 2·5 kips per sq. ft., and an effective depth of 22·5 in.

$$\therefore \text{ Max. B.M. on a span of 10 ft.} = \frac{wl}{10}$$

$$= \frac{2{\cdot}5 \times 10 \times 120}{10} = 300 \text{ kip-in.}$$

$$\frac{B}{bd^2} = \frac{300 \times 1{,}000}{12 \times 22{\cdot}5 \times 22{\cdot}5} = 49{\cdot}3.$$

As this is less than 95 the concrete will be safely stressed, so that we need compute only the steel required.

$$\text{The area of steel required per foot} = \frac{300}{16 \times {\cdot}9 \times 22{\cdot}5} = {\cdot}93 \text{ sq. in.}$$

We will have three $\frac{7}{8}''$ φ bars at 8 in. apart, then one $\frac{7}{8}''$ φ bar at 12 in. pitch, next three $\frac{3}{4}''$ φ bars at 12 in. apart, $\frac{5}{8}''$ bars at 12 in. apart being used up to the wall.

Counterfort.—The resultant pressure above the slab is equal to $\frac{15{\cdot}8 \times 23^2}{25^2} =$ 13·4 kips per ft. width.

The moment about base of whole force carried by each counterfort =

$$B = 13{\cdot}4 \times 10 \times \frac{23}{3} \times 12$$

$$= 12{,}300 \text{ kip-in.}$$

We will take the width of the counterfort as 18 in. and to allow for the fact that the reinforcement is inclined we will take the effective depth as 10 ft. = 120 in.

We then have $\frac{95\ bd^2}{1{,}000} = \frac{95 \times 18 \times 120 \times 120}{1{,}000} = 24{,}700$, which is equal to the concrete resistance of the section, and is much in excess of the bending moment which we have to carry.

We therefore calculate the reinforcement required from an assumed lever arm of ·9*d*.

$$i.e., \text{ Area of reinforcement} = \frac{12{,}300}{16 \times {\cdot}9 \times 120}$$

$$= 7{\cdot}13 \text{ sq. in.}$$

We will use 9—1″ φ bars giving $A = 7{\cdot}07$; we can justify our adoption of an area a little less than that calculated because if we worked it out accurately by the specified formula we should find that the lever arm is a little more than ·9*d*.

We have next to design the *shear reinforcement* for the counterfort

Taking first the horizontal reinforcement, we see that this is necessary to transmit the force transmitted from the wall slab to the counterfort.

If we turn *Fig.* 27 anti-clockwise until the wall slab is horizontal we see that this slab is loaded by the earth pressure and is suspended from the counterfort.

If we take stirrups of $\frac{5}{8}''$ φ bars bent round as shown in *Fig.* 32 we see that the tensile strength of each stirrup $= 16 \times 2 \times {\cdot}306 = 9{\cdot}8$ kips.

Starting from the bottom, where the earth pressure $=1$ kip per sq. ft., we see that the tension transmitted per foot by the stirrup $=(10-1{\cdot}5)1=8{\cdot}5$.

$$\therefore \text{ Length which one stirrup can carry } = \frac{9{\cdot}8}{8{\cdot}5} \times 12 \text{ in.}$$

$=13$ in., and allowing for the decrease in pressure shown by the pressure diagram we will make this 15 in. We will place the first stirrup 6 in. above the bottom of the wall slab.

The mean pressure over the next length will be approximately $\frac{21}{23}$ of its previous value, so that the pitch will be $\frac{15 \cdot 23}{21}=17$ in. approx.; we will make this 15 in., and then increase 3 in. each time as shown in *Fig.* 29 up to 2 ft. 6 in.

The vertical shear reinforcement has to carry the pressure given by the resultant pressure diagram shown in *Fig.* 30.

Taking double stirrups formed of ¾″φ rods, we see that the strength of each is $16 \times 2 \times {\cdot}441=14{\cdot}1$ kips; if the first is placed 2 ft. 6 in. from the right-hand end, we see that since the pressure here shown on *Fig.* 30 is 1·9 kips per sq. ft., the stirrup will do for $\frac{14{\cdot}1}{8{\cdot}5 \times 1{\cdot}9} \times 12$ in. $=10{\cdot}5$ in. We will therefore put the next one 1 ft away. The mean pressure at that point is 1·5 kips per sq. ft., so additional spacing $=\frac{1{\cdot}9-1{\cdot}5}{1{\cdot}9} \times 10{\cdot}5=2{\cdot}2$ in. We therefore space the next at 14 in., gradually increasing the spacing as shown in *Fig.* 29.

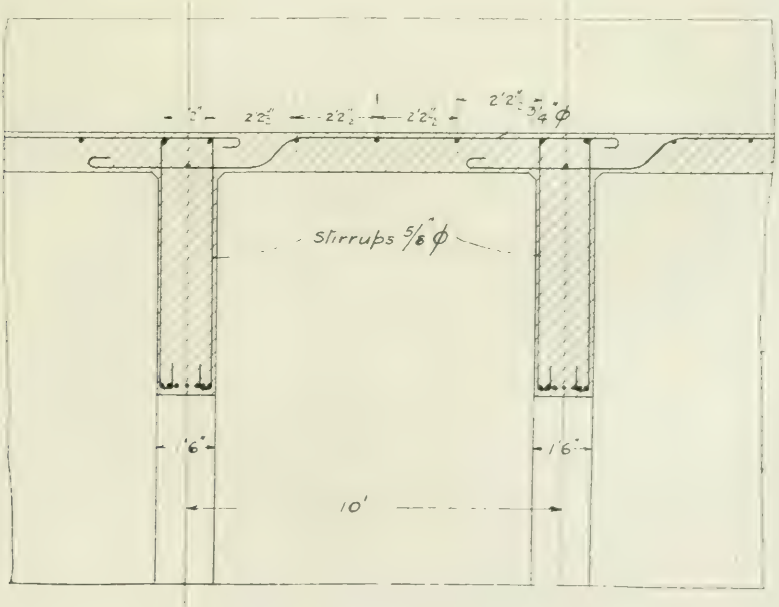
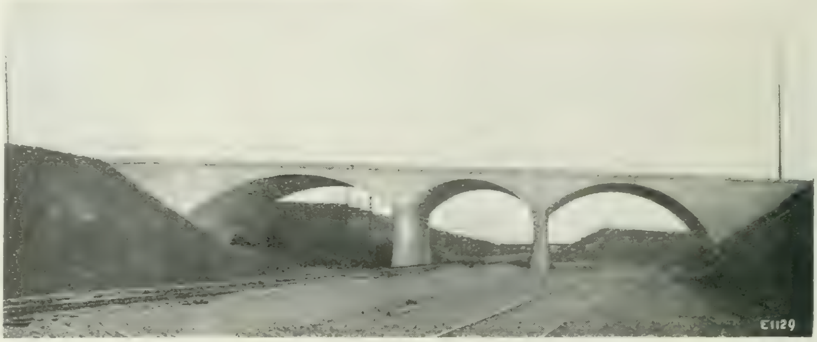


Fig. 32.



Reinforced Concrete Viaduct at Odense, Denmark.

SOME REINFORCED CONCRETE BRIDGES.

The following are some interesting types of Reinforced Concrete Bridges erected on the Continent. We are indebted to Messrs. Christiani & Nielsen for our illustrations and particulars.—ED.

GENERALLY speaking reinforced concrete has been far more widely used for bridge building on the Continent than has been the case in the British Isles, and pontists will find that almost every type of structure has been experimented upon with widely differing results. Whereas the development of brick and stone bridges may be traced in regular sequence through ancient and medieval times, the modern engineer appears to be evolving concrete constructions following several main types, and the four bridges here illustrated (each of which expresses a separate and distinct principle) are of interest to all interested in bridge and viaduct construction.

Fig. 1 shows a bridge or viaduct built for the Imperial Russian State Railways which forms the connecting link between the Russian and Finnish systems and which has a length of 2,000 ft.

Owing to the treacherous nature of the subsoil and the loads to be carried, piles were driven to a depth of 60 ft. below ground surface, and on the caps of these piles reinforced concrete supports were formed in pairs, thus forming a series of bridges with spaces between them. The connecting links, which are clearly shown, when lifted into position rest on outer ledges of each pair of supports, thus allowing for expansion, which is inevitable with the climatic extremes of the country, and at the same time allowing the whole structure to take an even bearing upon its foundations. *Fig.* 2, which shows three bays of the whole, is self-explanatory.

A more normal type is shown at the commencement of this article, which represents a viaduct at Odense, Denmark, and which is of arched

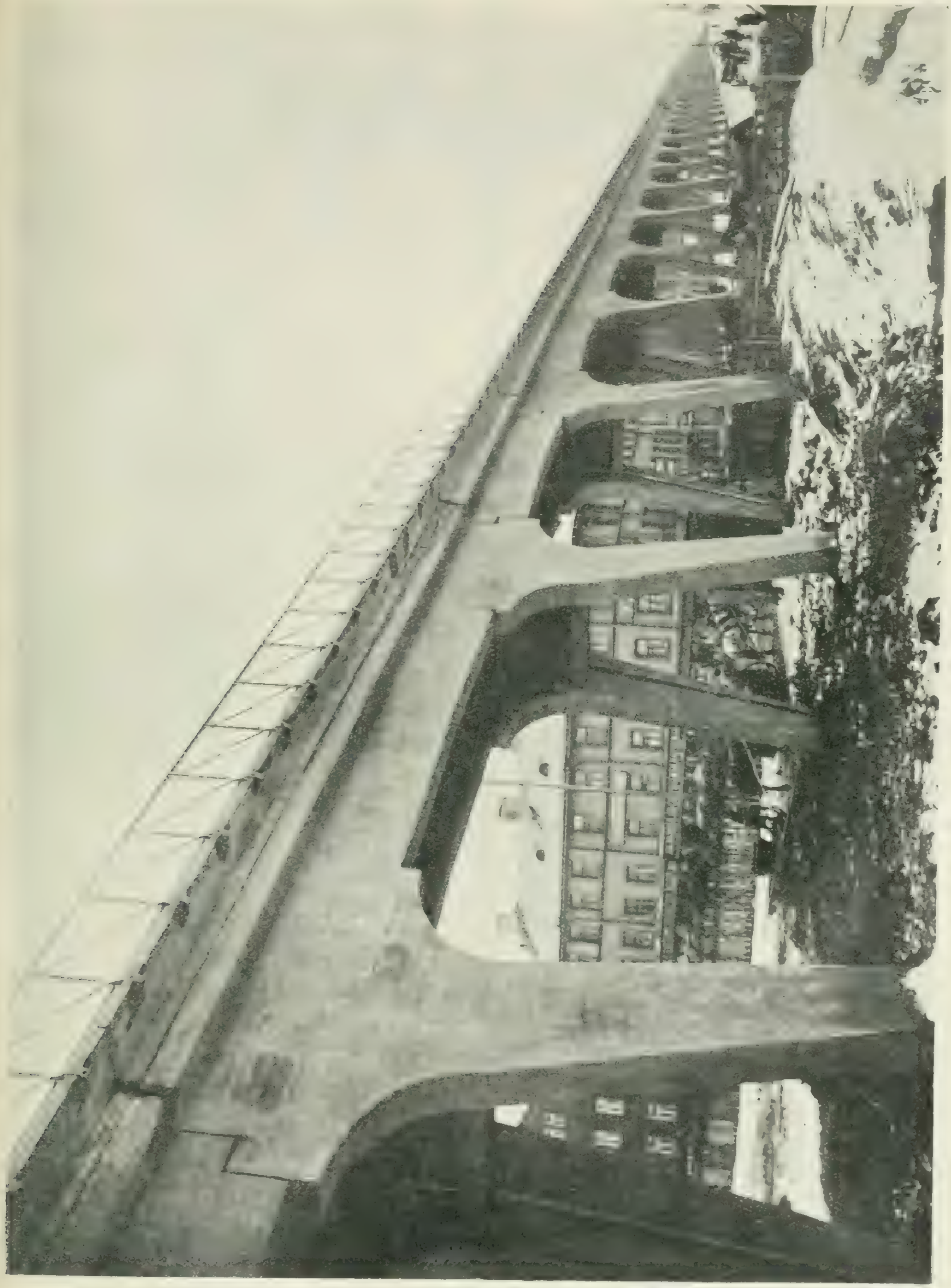


Fig 1 Viaduct built for Russian State Railways]

REINFORCED CONCRETE BRIDGES.

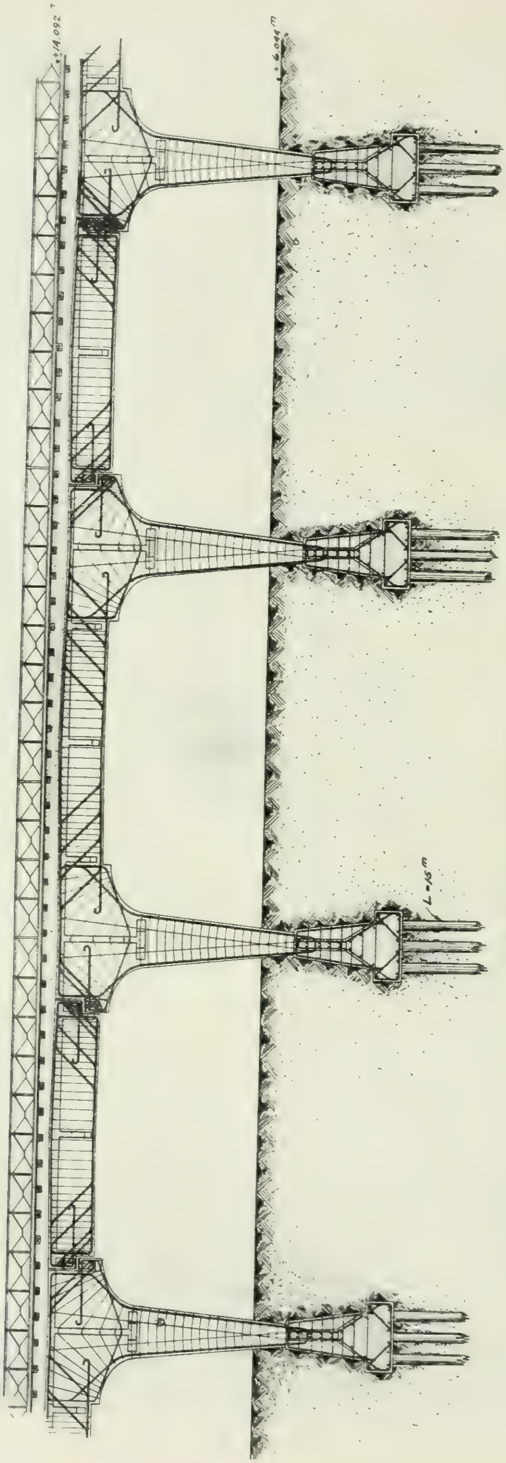


Fig. 2. Bridge at Petrograd for Russian State Railways.
REINFORCED CONCRETE BRIDGES.

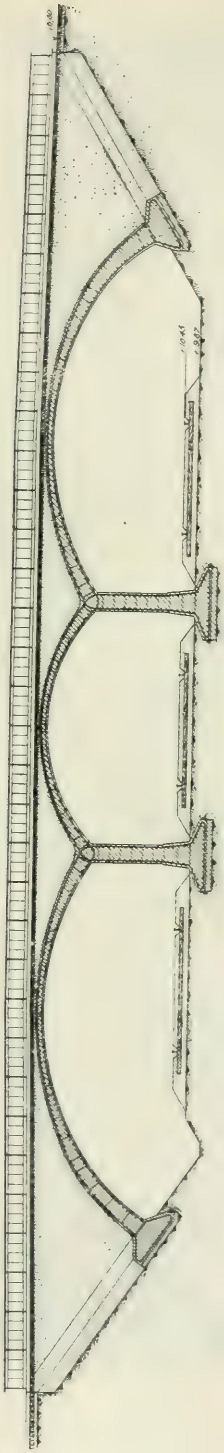


Fig. 3. Viaduct at Odense, Denmark.

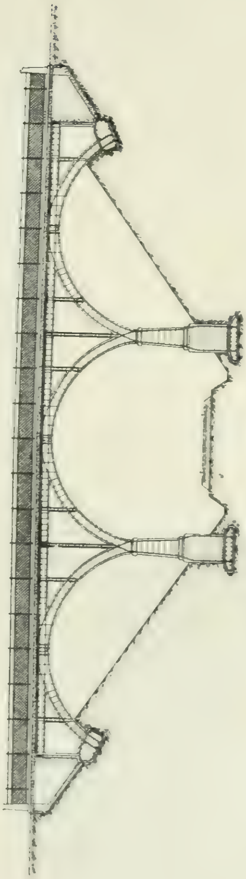


Fig. 4. Bridge over the Railway at Vejle, Denmark.
REINFORCED CONCRETE BRIDGES.

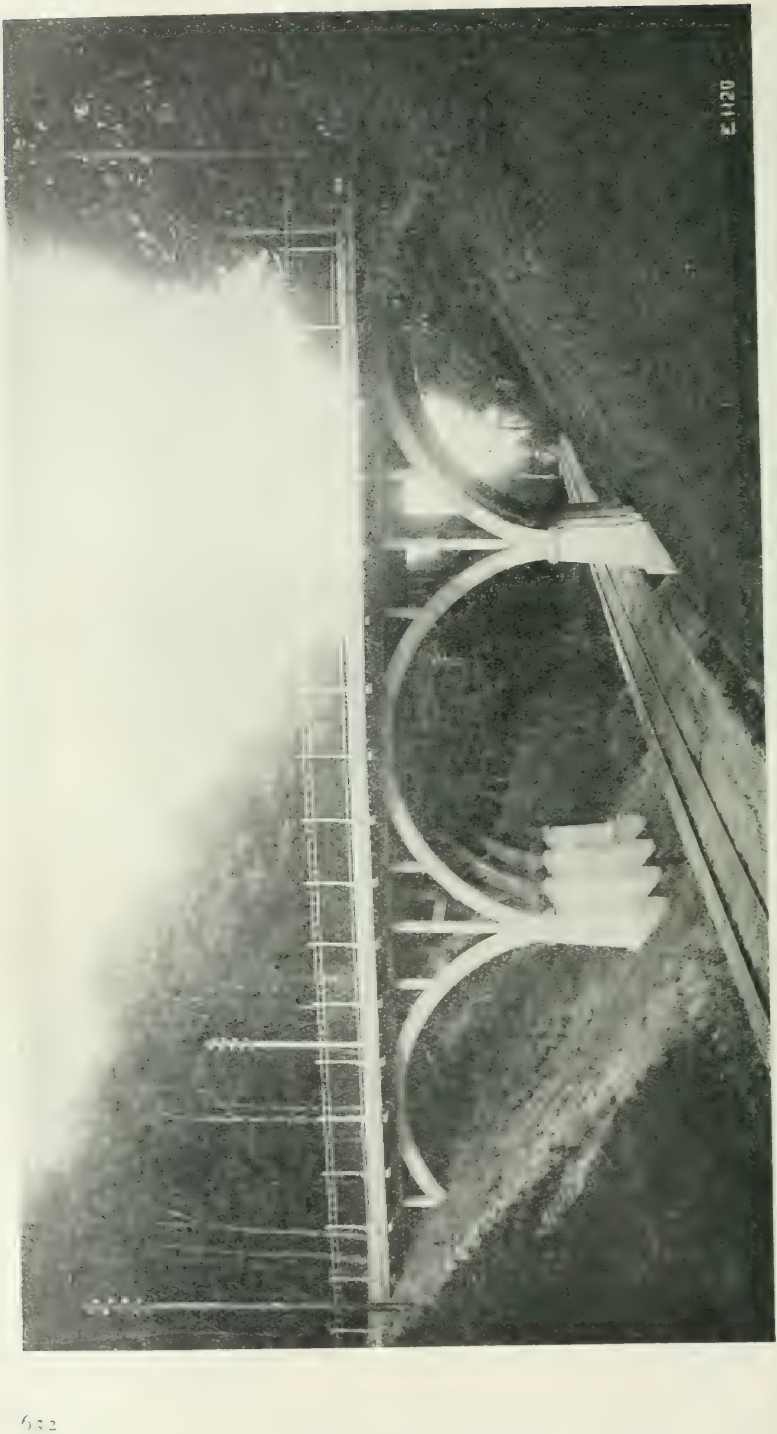


Fig. 5. Bridge over the Railway at Vejle, Denmark.

REINFORCED CONCRETE BRIDGES.

slab form with earth filling. The general lines of construction are shown in *Fig.* 3. As will be seen by the photograph, the whole structure crosses the railway at an angle, and the small distance between soffit of crown and road surface is worthy of note.

An entirely different type is shown in *Fig.* 5, which shows a bridge over the railway at Vejle, Denmark. It consists of a series of four piers on either side, connected by arched concrete ribs, whilst similar ribs on the outer side are connected to a continuous abutment beam. A beam carried through the crowns of the three arches supports the footway, which is widened out about 3 ft. on either side by a series of cantilevers projecting from the main beam. Ties and stiffeners strengthen and connect the whole construction, which is shown in the drawing, *Fig.* 4.

In *Fig.* 6 is shown a bow-string arched skew bridge which crosses the railway at Odense, Denmark. The work is designed as a series of three arches, crossing the railway cutting, and rests on four reinforced concrete piers, the stresses from the outer ends being taken by monolithic concrete retaining walls.

All these bridges were designed and executed by Messrs. Christiani & Nielsen, of 25, Victoria Street, Westminster.

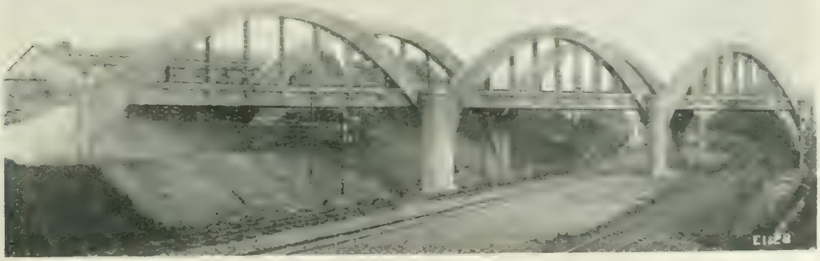
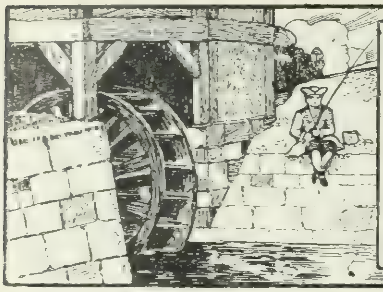


Fig. 6. A Bow-String Arched Skew Bridge at Odense, Denmark.

REINFORCED CONCRETE BRIDGES.



THE HOUSING PROBLEM.

Extract from the Report issued by Sir J. Tudor Walter's Committee, appointed by the Local Government Board to consider Questions of Building Construction in connection with the Provision of Dwellings for the Working Classes.

In another part of this issue we have referred to the Report just issued on the Housing Question, by the Tudor Walter Committee. In the following pages we reproduce that part of that section of the Report dealing with Construction, and which is of special interest to our readers.—ED.

Part IX.—Economy in Construction.

173. In considering the present position of house building as a craft or group of crafts with a view to reporting upon economy in construction, we think it well to recall how that position has been reached ; for no country has a finer tradition in reference to the building of the small house than our own. Yet cottage building during the last century came to be regarded as the easy job of the building trade, requiring neither skill in design nor science in erection. Seeing the ease with which local builders had erected successful cottages all over the country admirably adapted to the ideas and conditions of their day, the industrial age when it needed to carry out urban housing on a wholesale scale and under quite new conditions entirely overlooked the accumulated traditions of centuries of local experience which had guided the design and construction of the old country cottages in the different districts, and which had evolved those many beautiful local types that still excite the admiration of the world. Hence, while science and skill were devoted in ever-increasing measure to the development of industrial processes, no such attention was paid to house building. In view, however, of the multiplicity of the requirements of human life to be provided for, and the diversity of materials, processes, and skilled labours which have to be assembled and combined, each in its due order and under the proper conditions which alone ensure success, the cottage must be regarded as one of the most complicated and difficult of productions. In the absence of traditional skill and guidance, which rapidly changing conditions have largely destroyed, such a product needs scientific study of all its parts and thorough organisation of its erection, if a result at once efficient and economical is to be secured.

174. A certain limited number of skilled contractors have undertaken the building of small houses on a large scale. Such contractors have attained considerable success in producing at a remarkably low cost a few types of houses which had become customary. Unfortunately, though very naturally, they have largely accepted the type which had grown up in the period of neglect. Improvements have indeed been made from time to time, and certain standard types of plan and construction have been demonstrated by experience to be cheap under general conditions, and to be acceptable to the tenants, at least in the absence of anything more attractive ; there is in this experience of cheap building a valuable basis which is deserving of careful study.

175. During the last 20 or 30 years, however, there has been a very great revival of interest in the small house as a problem of planning, design, and construction ; architects, builders, and social reformers have studied the question and together tried numerous experiments. Many new types of cottage have been worked out and tested many designs of great beauty produced, and in some districts there may now be found small suburbs, villages, and estates consisting of such houses, or at least scattered examples sufficient to show the general tendency which has developed as the outcome of these efforts. Some of these examples have not only been admirable in plan and design, but have also proved economical in construction and have realised for the owners rents which have given a good return for the outlay. This movement has for some years been running parallel to speculative house building ; it has only hitherto been responsible for a small though a growing percentage of the houses built ; its influence, however, by way of example, in improving the standard of house building, has been more widely extended.

176. Such was the position reached before the war arrested the building of houses completely for three or four years, and changed the whole conditions on which both branches of the industry were based. After the war a new start must be made, and success can only be secured by a careful consideration of new conditions in the light of the best experience of the past. We have, therefore, tried to keep in view in perparing this part of the Report the following considerations :—

1. That it is desirable to take advantage of the best results of the experimental work which has been carried out by individuals, public utility societies, and others, who have been building, not with the sole aim of securing the maximum financial result, but with a view to producing the best types of house that could be built to yield a moderate return.
2. That the methods of economical building adopted by the best builders who have concentrated their skill and attention on building cottages on a large scale are deserving of careful study.
3. That the up-to-date methods of business organisation, scientific costing, standardisation, etc., which have been found effective in other industries and which the pressure of war has caused to be more generally adopted are applicable with due adjustments to the cottage-building industry.
4. That the war has changed many of the conditions of the industry, has altered the positive and relative values of most of the materials and labours connected with the processes of building, has caused a scarcity of some materials which is likely to persist for a considerable period after its close, and has rendered necessary a reconsideration of the whole subject of house construction.
5. That a detailed study of each component part and process connected with house building is required to determine what are the best methods of securing the greatest economy and efficiency in the light of the new circumstances which will be likely to prevail.
6. That the large number of houses required immediately after the war, and the probability that these will be erected under some degree of Government influence or control, will afford an opportunity for securing economies due to organisation and standardisation applied on a scale not usually practicable.
7. That certain special conditions must be considered in reference to building immediately after the war which may be expected to endure for a limited time only.

177. At an early stage we reached the conclusion that so far no revolutionary developments of materials or processes had been evolved that were likely to result in sensational changes in the character of house building, but that there were a number of suggestions in many branches of the work which deserved investigation ; that, in fact, the whole of the processes called for review, in the hope that a number of improvements and economies might be found, the accumulated effect of which might be considerable though individually they might seem to be small.

178. Further, we found that many materials and methods believed to be economical or efficient, or to promise suitable substitutes for materials likely to be scarce, would need to be investigated and tested scientifically in order to determine their durability or other qualities and the safe limits of their use before they could be recommended. We, therefore, sought the assistance of the Department of Scientific and Industrial Research, and, as a result, a small Committee was appointed to undertake the necessary investigations.

A number of researches have been put in hand, the results of which it is proposed to embody in a subsequent report so soon as they are completed ; for the present it will only be possible to indicate in these cases the apparent tendency of the investigation in so far as that has already been made clear.

179. In comparing the exact costs of different materials and processes, we have found it impossible to do as much useful work as we would have wished to do if our inquiry had taken place in normal times. Pre-war prices no longer form any useful guide ; even the relation of these prices has ceased to be reliable ; the variations not only between the prices, but in the relation of the prices of one class of work or material to another in different districts of the country, are so great that we have felt it useless to attempt to deal in exact figures with this aspect of the matter. Even in pre-war days great difficulty was experienced in relation to house building owing to variations in prices as between different localities and different contractors, variations for which it was not easy to account. It is probable that such variations were partially due to a want of scientific costing in the production of the component parts of the houses and to the office methods of many builders engaged in the industry.

The following examples, taken from actual costs of works executed in 1917, show the percentage of extra cost in each case over the costs of similar works in 1914, and the varying relation of different classes of work in different districts :—

Trade.	District A. Per cent.	District B. Per cent.	District C. Per cent.
Brickwork	41 ...	... 67 ...	... 86
Slating	22 ...	... 74 ...	... 65
Carpenter's work	129 ...	... 164 ...	... 181
Plumber's work	79 ...	... 169 ...	... 119

180. Owing to the diversity of the trades affected and the great number of the materials, fittings, and different kinds of articles which go to make up a finished cottage, it is obvious that a complete investigation into every one of these could not be carried out by us within the time available. We have, therefore, endeavoured to concentrate attention on more important items, on those most likely to be affected by new conditions due to the war and on those in connection with which any improvements or suggestions towards economy have been definitely brought before us in evidence.

181. We have been struck by the exaggerated idea, widely held, as to the possibility of economies in certain directions ; we have been repeatedly assured that the adoption of this or that method or process would secure a reduction in the cost of the cottage of 5, 10, or even 20 per cent. With a view to arriving at some definite scale of proportion, the materials and labours in connection with one or two sample groups of cottages were investigated, and the percentages which each group represented in the total expenditure on the cottages were worked out. The following tables give one or two examples of the relative percentages :—(I.) on the basis of a priced schedule of quantities in which the labours and materials are taken together and represented mainly under the headings of different trades concerned, and (II.) based on the actual costs of fourteen suburban cottages built by direct labour, in which the materials are separated from the labour and are grouped mainly in accordance with the different trades supplying them.

By reference to Table I. it will be seen that the highest figure represented by any one trade is that of the bricklayer, which includes much besides the actual shell of the building, and this only represents 31 per cent. of the total cost of the building ; while by reference to Table II. it will be seen that bricks only represent about 10 per cent. of the total cost of the building. When, therefore, it is suggested that the adoption of certain concrete blocks for walling in place of brickwork can result in a saving in the total cost of 25 per cent., a suggestion which is not infrequently made, it must be obvious that no such saving on this one item is possible. None the less, it remains true that the bricklayers' trade, taken as a whole, is one of the largest, and that the woodwork represents the next important element in the cost. It is interesting to note that the labour, which is mainly labour of erection, though a certain amount of shop labour in preparing joinery is included, represents by far the largest single item in the cost. In the instance recorded in Table II. the item for overhead charges includes a small sum for architect's fees, and the remainder consists of a 10 per cent. allowed on the cost of labour and materials to cover establishment and plant charges ; these may vary somewhat from ordinary contract conditions, but will not materially affect the relative figures as between the different classes of trades and labours.

Proportions of the Total Cost of a Cottage represented by different Materials and Labours.

TABLE I.—Based on Priced Bill of Quantities for a pair of Rural Cottages. Labour and Materials taken together given in Percentages of the Total Cost.

	Per cent.
Preliminary items, insurances, etc. ...	3·25
Excavator and concretor	5·00
Drainer *	1·00
Bricklayer, etc.	31·00
Concrete block partitions and fixing ...	2·25
Roof tiler	4·50
Carpenter and joiner	26·37
Ironmongery	1·75
Smith and ironfounder, including fire grates	4·13
Plasterer	11·25
Plumber	5·75
Rainwater butts	1·00
Painter and glazier	2·75
Total Cost	100·00

TABLE II.—Based on the Actual Cost of 14 Suburban Cottages built by Direct Labour. Labour and Materials given separately.

	Per cent.
Timber manufactured and unmanufactured	17·48
Bricks	9·80
Roof tiles, ridge, etc.	1·65
Glazed and floor tiles	0·48
Sanitary ware and pipes...	2·30
Portland cement	2·12
Plaster and mortars	3·57
Ballast, sand, etc.	1·82
All castings	4·13
Lead, sheet, and pipes	2·18
Locks, latches, ironmongery, nails, screws, and taps	2·81
Paint, varnish, wallpaper, putty, glass, oil, glue, etc.	2·38
Gas fittings	0·75
Sundry materials	1·26
Labour of all kinds	35·77
Overhead charges of all kinds, including fees	11·50
Total Cost	100·00

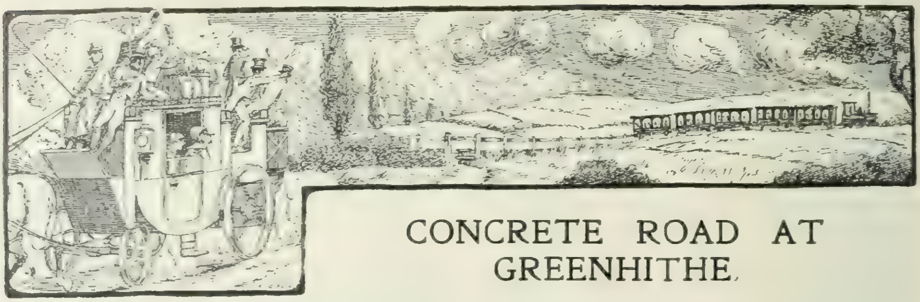
* Drainage item small, as earth-closets were provided.

182. In considering the order in which the different branches of the subject should be pursued, it seemed most convenient to take the general order usually adopted in specifications and schedules of quantities, grouping the different materials and processes under the headings of trades with which they are concerned, and this order has been generally adopted. There were, however, certain matters of outstanding importance to which it seemed desirable to give preference ; these were first considered, and referred to the Research Committee for certain investigations to be carried out. The two most important matters were :—

1. The consideration of possible substitutes generally or locally advantageous in place of bricks or stone for walling in connection with cottages, particularly the question of the use of concrete for such purpose.
2. The finding of substitutes for the various uses of timber in cottage construction.

183. Owing to the extent to which brickworks have fallen out of commission and have been occupied for storage or other purposes, or have been working on a very limited output owing to the shortage of labour, there is at any rate considerable probability that bricks may not be available in anything like adequate quantities to meet the building demands in the period immediately after the war. Moreover, bricks are bulky, and there is every reason to expect that very heavy traffic will be thrown on the railways during the period in question, and that the transport of bricks for any considerable distance will be very undesirable from the traffic point of view, and may quite possibly have to be avoided even in cases where financially it might be economical. In these circumstances the question of possible substitutes appears to be one of considerable importance ; it is not, however, one of great simplicity ; other factors besides the theoretical ones have to be considered, and particularly is this the case in reference to the emergency housing to be undertaken immediately after the war. It may well be that the employment of new methods of construction or the adoption of new materials which would ultimately prove economical might on the contrary turn out to be locally or temporarily expensive owing to the absence of skill on the part of the available workmen or lack of experience on the part of the local contractors.

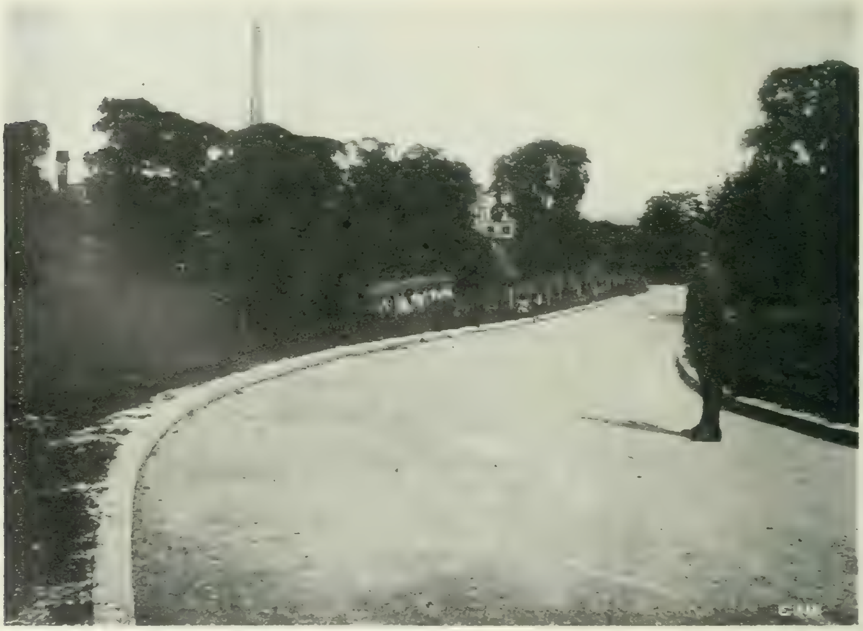
(*To be continued.*)



CONCRETE ROAD AT GREENHITHE.

At the present time when the rebuilding of many of our roads is claiming the attention of the authorities, and the use of concrete for some of them is being considered, no doubt recent examples of concrete roads built in this country will be of interest to all concerned.—ED.

In the June number of *Concrete and Constructional Engineering* reference was made to concrete roadways in connection with industrial works, one example cited being that which forms the approach to the Ingress Abbey works of the Wall Paper Manufacturers, Ltd., at Greenhithe. We are now able to show a photograph of this road, which was laid during the spring of this year and has been open to traffic some six or seven months.



The kerbing, 6 in. wide, of plain concrete consisting of a 3 : 1 mixture of sand and cement was first laid *in situ*, contraction joints being placed at intervals of 12 ft. This then served as side forms for the roadway itself, which was constructed in two courses. The concrete for the lower course of 4 in. was composed of washed and crushed pit ballast mixed with Portland cement in the proportion of 6 : 1 ; on this was deposited a wearing coat 2 in. thick and proportioned 3 : 1. The concrete was laid in alternate bays, care being taken that the work on each bay was continuous. As the road was reinforced no " joints " in the usual acceptance of the term were provided, but a single thickness of tarred paper was placed against the ends of the completed bays before the intervening spaces were filled in.

Each bay was provided separately with its own section of reinforcement, which consisted of B.R.C. fabric, and was placed in the centre of the concrete, that is to say, 3 in. from the bottom. In order to secure for the metal complete protection, and immunity from risk of corrosion, the fabric was so placed that it did not extend the full length and width of each bay, but stopped 2 in. short of the ends and of the kerb on each side.

The traffic consists mainly of large motor lorries and steam tractors, and so far the road is said to have given every satisfaction.

MEMORANDUM.

Concrete Roads.—In a recent issue of *The Autocar* Mr. Percy Boulnois (Chairman of the Council of the Roads Improvement Association) briefly discusses some points for and against the adoption of Concrete Roads. We do not think we can do better than to reproduce the short notes which appeared in the above-mentioned journal :—

" An ordinary Portland cement concrete road with a smooth surface is an ideal highway for all descriptions of motor vehicle or bicycle if the wheels are provided with rubber tyres. Why is it, therefore, that roads of such construction have scarcely been tried in the British Isles, whereas in America, Canada, and other countries, many millions of square yards of concrete roads have been laid with marked success ?

" *Constructional Conditions to be Observed.*—It is a little difficult to trace the reasons for this antipathy amongst the road makers of our country, but it may probably arise from the following causes :

" 1. At least three or four weeks should elapse for the concrete to set hard before any traffic is allowed on its surface, and this, in some cases, is almost prohibitive where the traffic cannot possibly be diverted.

" 2. Very close supervision is necessary whilst this description of construction is proceeding—a little carelessness on the part of the workmen will turn out a batch of concrete of inferior quality, with disastrous results.

" 3. Unless precautions are taken in laying the concrete, the surface is liable to crack in an unsightly manner, and there is no doubt that greater care has to be exercised in the building of a concrete road than in dealing with any other form of construction.

" 4. When openings are required for the purpose of laying gas or water mains, or for any other purpose, the breaking-up of such a material is more difficult and troublesome than is the case with other forms of construction, and the reinstatement of such a road requires very special care.

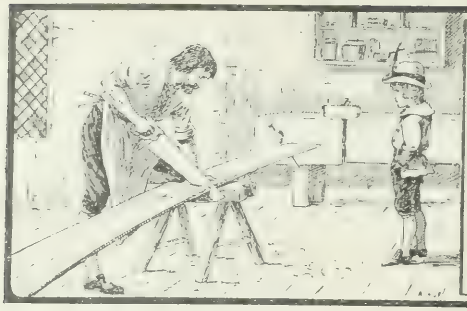
" 5. The cost has hitherto worked out at about 6s. per sq. yd., though this cost has been mainly due to the small area treated. In America and Canada the cost has been reduced by the employment of special machinery on large areas of roads, thus greatly reducing the charges in respect of labour.

" In spite of these drawbacks, however, an unsurfaced concrete road has many advantages. It will withstand the heaviest traffic, especially if it is slightly reinforced with steel rods or netting. It presents an excellent surface for all classes of traffic, though somewhat noisy where metal tyres are used on the wheels of the vehicles. It is never slippery under any conditions of weather, and can be laid on quite steep hills. The camber, or barrel, of the surface can be reduced to a minimum, owing to the impervious nature of the material, and it has no tendency to spread, creep, or become wavy, which are some of the inherent faults in roads constructed with bituminous compounds. It is an economical road, for when once constructed it requires little or no repairs for many years, especially if the surface be occasionally tar painted as needed.

" *To Meet Post-war Traffic Requirements.*—A concrete road naturally becomes harder and harder with time, while it is easily kept clean, has a good appearance, and the tractive force required to propel a vehicle upon it is low. It requires no artificial foundation, unless the natural ground is very soft, as if laid 6 in. thick and reinforced it will carry very heavy loads without sinking.

" There can be no doubt that after the war the use of our roads for the transport of merchandise will largely increase in intensity, and it will be necessary to construct our roads to stand up to this heavy traffic. It is to be hoped, therefore, that the road authorities, and their expert advisers, will be able to construct our roads on modern lines, and possibly in this connection concrete may be found, in certain localities, to be the best form of construction to meet the requirements.

" Which of our county or borough surveyors will be bold enough to act as a pioneer in this movement ? "



ASBESTOS CEMENT.

There has been a considerable increase in the use of asbestos cement in the building industry during recent years, and the following notes should be of interest.—ED.

Introduction.—The important part that has been played by asbestos cement during the war is scarcely realised, because so much of the work in which it has been used constitutes special work that cannot be illustrated and described without the consent of the authorities.

The material has, however, proved invaluable on account of its peculiar properties, and it is likely to be even more extensively employed in the future as these properties become more generally known, and, furthermore, considerable improvements have been made in the manufacture since it has become a British industry. One of the chief advantages obtained with asbestos cement is that of lightness, combined with comparatively great strength, and this is of particular importance for some classes of work, while its adaptability to any reasonable shape makes it suitable for a number of purposes in connection with buildings.

Historical.—Asbestos cement, tiles, and sheets were originally manufactured on the Continent under what were known as the Hatschek patents, and up to a few years ago this country was dependent on Germany and Austria for its supply. The passing of the Patents Act in 1907, however, brought about a change, as the patents in question, it is interesting to note, were the first to come before the courts under this Act. After a lengthy hearing it was decided that the production of these tiles and sheets could not be restricted to foreign countries, because the patentee used the monopoly conferred upon him by his patent rights in this country to exploit the articles manufactured abroad, and did not establish any part of the industry here. On appeal to the High Court this decision was upheld, with the result that important works have been established in Great Britain, and we have been rendered independent of foreign supplies, while providing employment for many workers. The establishment of this new industry has been very timely under the circumstances, as the manufacture was in a favourable position when the war broke out. It is no exaggeration to say that many million square feet have been used by the Government during the last four years for various purposes in connection with war supplies; thus the importance of the material will be evident.

Manufacture.—The substance is manufactured with asbestos fibre and Portland cement, which are mixed in proportions usually about 1 to 6, and as the fibre acts as a kind of reinforcement to the cement, it is essential that the asbestos should be uniformly distributed so that the fibres interlace with each other. In some of the cheaper varieties made on the Continent, the material is formed by pressing out into moulds a cement and asbestos mixture in jets, with the result that the product lacks elasticity and homogeneity, and it is brittle and unreliable.

The asbestos used in this method is usually weak and powdery, and not only is there a want of continuity in the fibre, but the powdery material is liable to adversely affect the setting of the cement. In the British method of manufacture, specially selected fibre is used, and after mixing the material is passed through specially designed rolling mills in the form of layers, the thickness of which is about 0·007 of an inch, and these layers are so compressed that the adhesion is perfect, and after reaching the mature stage the finished sheet is devoid of any stratification. The thickness is therefore built up of several layers or films, sometimes twenty in number, and in each of these layers the asbestos fibre is uniformly distributed and interlaced so as to constitute a species of tough woven fabric. Like other materials made with Portland cement, the strength increases with age, and exposure to the atmosphere increases the hardness, and does not tend to cause decay, as occurs with many building materials, unless some kind of preservative is periodically applied.

Owing to the close expert supervision that is employed during all the processes of manufacture, the up-to-date machinery, and the standardised methods adopted, the product is reliable on account of its consistent good quality, and the prejudice that existed against the material a few years ago has been entirely removed.

Advantages.—There are many features of asbestos cement which tend to increase the demand for supplies in the building trade, and not the least important of these is the fact that the material can be readily worked and quickly fixed with ordinary carpenters' tools. It can be sawn to required sizes or shapes, it can be drilled for bolts or rivets, or can be fixed with ordinary nails. If a perfectly true edge is required after cutting, it can be obtained by the use of a plane, and even large sheets are remarkably light and can be handled with ease, and there is no fear of breakage. The lightness is of importance when used for roofing, as the structural members required to support the material can be smaller than those necessary for other permanent forms of roofing. It requires no painting to protect it from the weather, and it is thus far more economical than corrugated iron, which needs continual painting to prevent decay, especially in some situations. The material has been extensively used for work in contact with acids and salts, and its resistance to the fumes or actual liquids has been proved to be excellent under the most trying conditions, while the non-absorbent nature and smooth unflaking surface are distinct advantages for almost all classes of work. Its incombustibility has led to its adoption as a fire-resisting protection to other materials, and its durability renders it an economical substance for roofs, wall and ceiling linings, and other similar purposes. As an insulator it is good, and this combined with its resistance to frost, rain, wind, and acids renders it a perfectly safe and satisfactory material to use under almost any conditions. It should be impressed upon the user, however, that these advantages will not always obtain with the cheap and inferior kinds, and only the best British makes should be adopted if real economy and satisfaction is to result.

Uses.—The material is obtainable in two forms—viz.: (1) As asbestos cement sheets in varying thickness from $\frac{1}{8}$ in. to 1 in., the standard sizes being 8 ft. by 4 ft. and 4 ft. by 4 ft., but sheets 6 ft. by 3 ft. can also be obtained when required; (2) as tiles for roofing work, these being of various colours, sizes, and shapes, and either plain or corrugated.

The sheets are used for various purposes, among which is that of lining walls and ceilings of various classes of buildings. They are usually fixed with edges butted together and nailed to timber joists or studding, the joints being afterwards filled in or covered with a strip of asbestos or wood according to the finished appearance required. When the joints are filled in a good even surface is obtained, which can be distempered, painted, or papered without any delay in waiting for setting and drying, as in the case of plaster.

Before decorating with ordinary oil paint, it is advisable to apply a coat of boiled linseed oil, to which 10 per cent. of liquid seccotine has been added, otherwise the paint is liable to be "patchy" and unsatisfactory in appearance.

The interior view of the bungalow sitting-room, illustrated in *Fig.* 2, shows the application of the material as a wall lining, and the effect is quite pleasing.

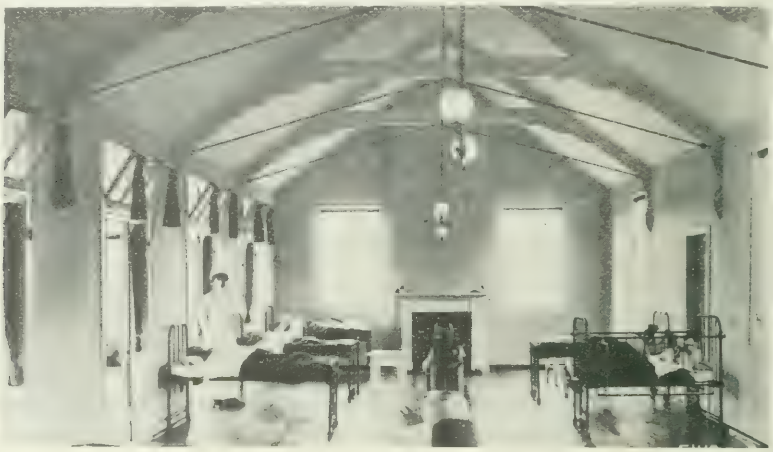


Fig. 1. Children's Hospital at Strathblane.

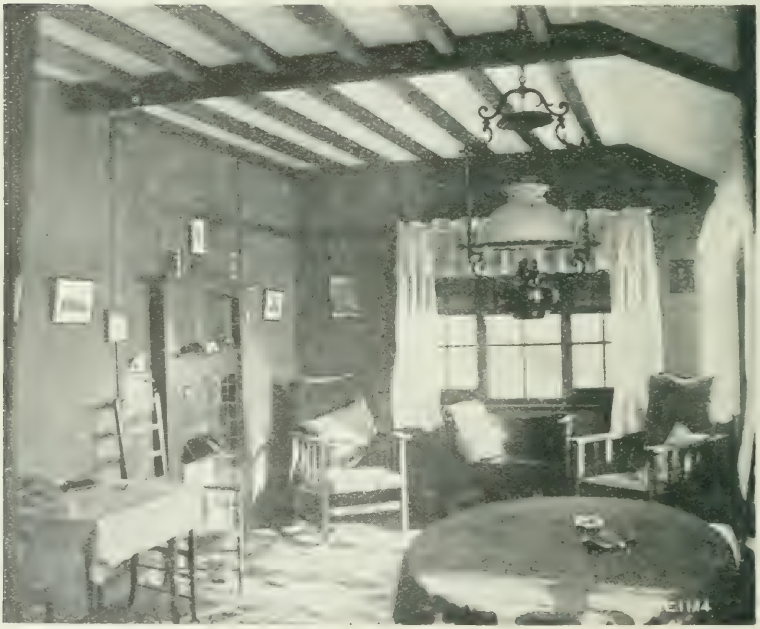


Fig. 2. Bungalow. Interior View—Sitting-Room.

Another example of its use is that given in *Fig.* 1, this showing the interior view of the children's hospital at Strathblane. It is eminently suitable for such work on account of its sanitary and fire-resisting qualities. An exterior view of this hospital is also given, as asbestos was adopted for the roof covering, in addition to the interior lining of the walls, this work being executed to the designs of Messrs. F. D. Cowieson & Co., architects, Glasgow, by Messrs. Turner Brothers Asbestos Co., Ltd., Rochdale.

An interesting example is that illustrated in *Fig.* 4 of the Church Army, Lord Kitchener Hut, where the walls and roof are constructed with Turner's asbestos cement.

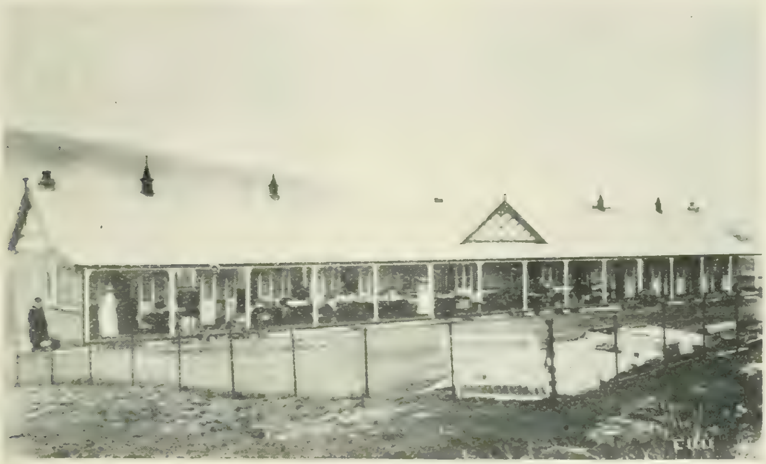


Fig. 3. Children's Hospital at Strathblane.

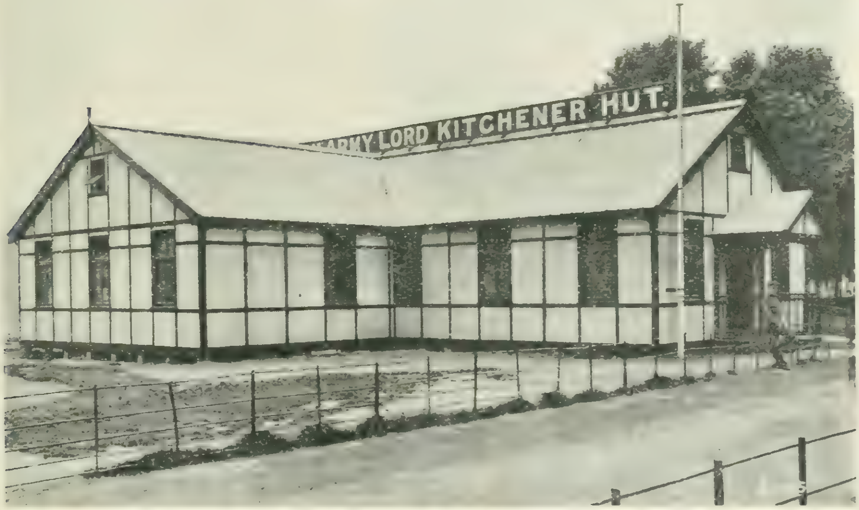


Fig. 4. Church Army, Lord Kitchener Hut.

and the successful external treatment with this material is worthy of notice. Numerous instances occur throughout the country of similar structures, as the speed with which the sheets could be handled and erected was of tremendous advantage in all war buildings, and the amount of labour required was reduced to a minimum.

In the case of linings to ceilings it is advisable to use sheets 4 ft. square, as these are more easily handled during fixing, and by means of strips of wood or abestos over the joints a very satisfactory panelled effect can be obtained. Sheets about $\frac{3}{16}$ in. thick should be adopted, and they are attached to the ceiling joists with butt joints, the fixing being accomplished with $1\frac{1}{4}$ in. Sherradised or copper nails at about 6-in. centres, and not less than $\frac{1}{2}$ in. from the edge of the sheets.

When used for partitions, the sheets are fixed to timber studs, which should be spaced at 1 ft. 4 in. or 2 ft. centres. Horizontal struts must be used between the vertical studs to form a bearing for the ends of the sheets, and the studding should be braced in the usual way to ensure rigidity. By using sheets on both sides of the timber, an economical and durable partition will be obtained with an appearance far superior to ordinary matchboarding, while the delay and disturbance caused by the use of plastering in offices and similar situations will be avoided.

(*To be concluded.*)

MEMORANDUM.

Concrete Bridges in Canada.—The double tracking of the North Toronto Sub-Division of the Canadian Pacific Railway between Leslie and North Toronto, which is nearing completion, involved the replacement of bridges (known as 0.9 and 1.8) which hitherto had been trestles constructed of steel. Owing to the high price of steel and the difficulty of procuring it since the war began, it was found, states a Halifax (N.S.) contemporary, that reinforced concrete competed successfully against steel. The bridges were, therefore, constructed of this material and it is stated that they are a triumph of railway construction work, No. 0.9 being 386 ft. long and 90 ft. high, carrying two tracks, and No. 1.8 of similar dimensions, but a three-track structure.

The spans of these two Canadian Pacific Railway structures are each from 35 ft. to 37 ft. long. Unit construction was employed. Each span was designed as two T-beams which, after being manufactured near the work, were laid side by side on the previously built reinforced concrete towers. The towers themselves are really reinforced concrete buildings constructed in the usual manner by means of wooden forms built around a steel reinforcement which was previously assembled and securely wired together.

When all was in readiness the concrete was poured by means of long spouts which led in several directions from the main mixing tower. The pouring of the concrete was maintained as continuously as possible until a whole tower was completed.

These two structures are provided with narrow sidewalks and handrails, which enable trainmen to move conveniently along side-standing trains.

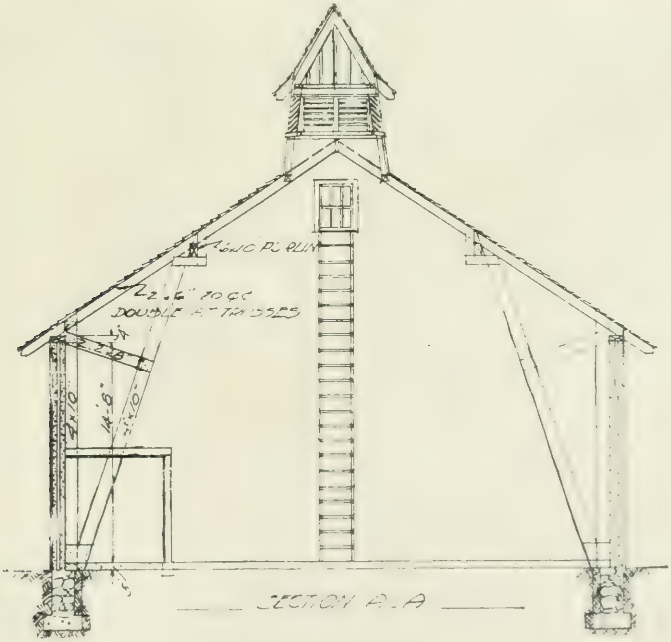
The method employed in the erection of the reinforced concrete spans is a specially interesting feature of the structures. Each slab, as a unit, weighed 55 tons, which was the limit load that could be handled by the Canadian Pacific Railway 100-ton standard wrecking cranes. The crane engaged handled no fewer than 110 slabs, each 55 tons in weight, or in all something like 6,000 tons, and all this was done without a single mishap to either men or material.

Another remarkable feature is that both structures were built without interruption from June, 1917, to July, 1918, which was a shorter period than would have been required to manufacture and erect similar structures in steel. Passenger and freight traffic on the Canadian Pacific Railway main lines was continued without interruption during the progress of these interesting works.

CONCRETE FOR FARM BUILDINGS.

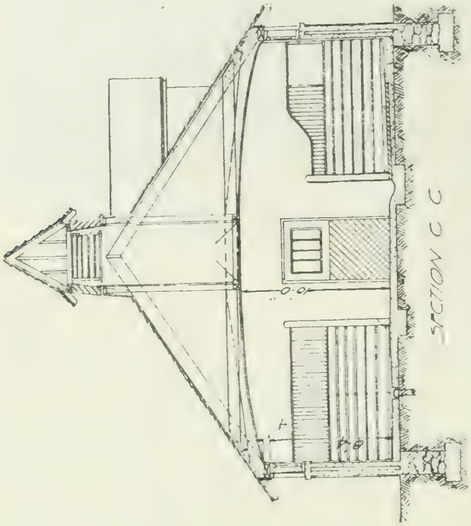
The accompanying illustrations show a group of barns, sheds, and silos constructed of concrete throughout. These buildings were constructed to provide the needs of an institution maintained by the Sisters of St. Joseph at Framingham, Mass., where a dairy farm is operated. A fire necessitated building a new farm plant throughout and the problem presented to the architect was to design a thoroughly practical set of buildings, moderate in expense, yet fire-resisting and demanding minimum upkeep.

The main group consists of a 75-ton hay barn, a 20-cow barn with 3-ft. box stalls, shed for young stock, bull pen, 100-ton silo, horse barn, feed rooms, wagon shed, machinery, and tool rooms.

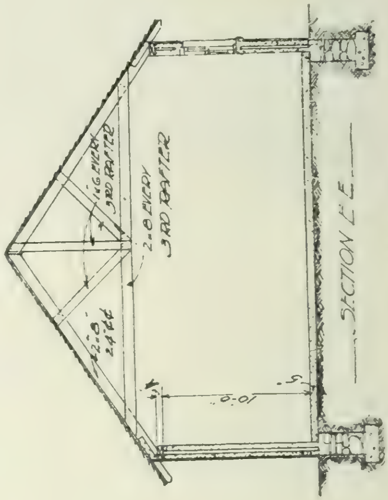


Section of Main Hay Barn.
Concrete Barns at Framingham, Mass.

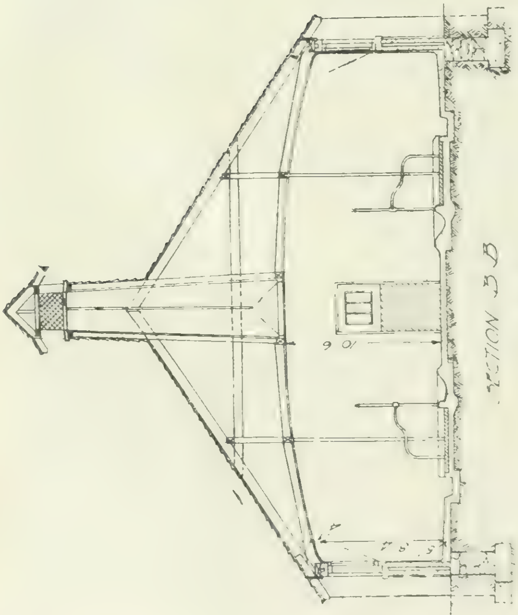
The dairy building is opposite the cow barn and contains the dairy room, wash room, boiler and coal room. Every precaution was taken to secure sanitary buildings, easily kept clean.



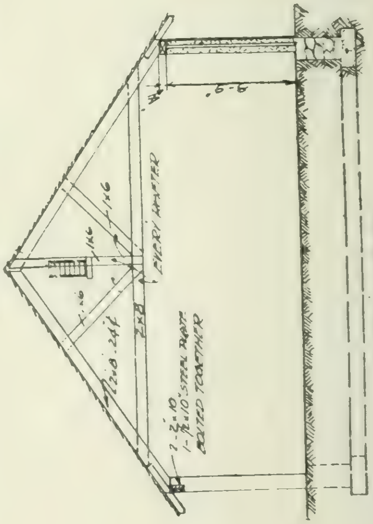
Horse Barn.



Young Stock Shed.



Cow Stable.

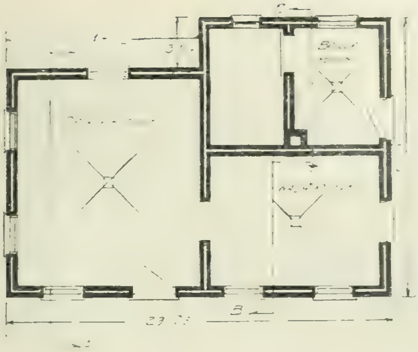


Machinery Shed.

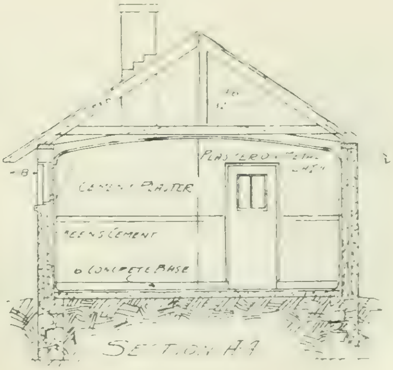
CONCRETE BARNS AT FRAMINGHAM, MASS.

The walls are of monolithic construction and double throughout, consisting of two 4-in. walls with a complete air space. A 1 : 2 : 4 mix was used with crushed stone as the coarse aggregate. The walls were built in

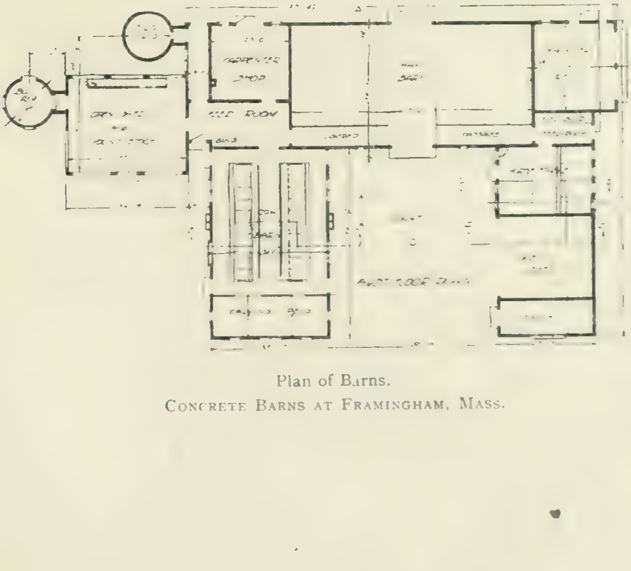
Barns and Silo under construction.



Plan of Creamery.



Section of Creamery.



Plan of Barns.

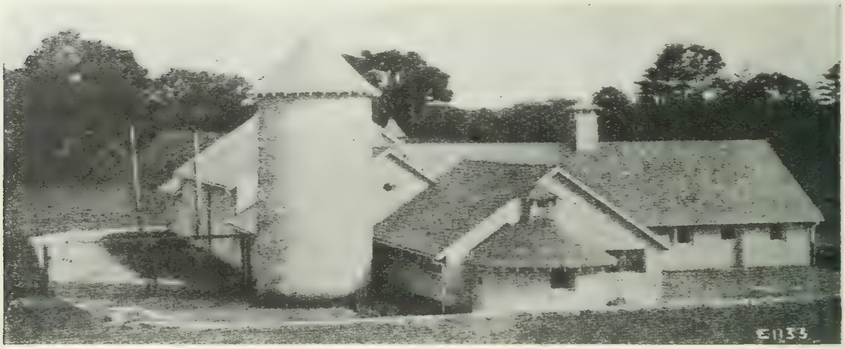
CONCRETE BARNS AT FRAMINGHAM, MASS.

the rough with wall machines and were stuccoed. The concrete was mixed and hoisted by hand, and with common labour. The floors are all on fill, and are concrete except in the stock shed, bull pen, and part of the hay barn, where earth floors are used. The horse and cow stalls are surfaced with wood paving blocks.

The dairy and stable are provided with arched ceilings of cement mortar on metal lath. All angles are coved. The roofs are slate on substantial wood framing.

The group of buildings was designed by Edward Burnett, of New York, and were built by J. B. Byrne, Inc., Cambridge, Mass.

For the above particulars and illustrations we are indebted to our contemporary *Concrete*, U.S.A.



A General View of the Completed Buildings.

RECENT VIEWS ON CONCRETE & REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE ROYAL INSTITUTE OF BRITISH ARCHITECTS.

A CHEPSTOW HOUSING SCHEME.

By WILLIAM DUNN, F.R.I.B.A.

A PAPER of special interest to the readers of this journal was read on November 18th before the members of the above Institute on the "Chepstow Housing Scheme," to which brief reference has already been made in this journal (see our issue of March, 1918, p. 118). The President, Mr. H. T. Hare, was in the Chair.

"A CHEPSTOW HOUSING SCHEME.

"Chepstow is in the Wye Valley, a hilly district famous for the beauty of its scenery. The site of the houses is about 28 acres in extent, and lies just outside the Port Wall. It formed a little valley, bounded on the northern side by the Port Wall on the crest of the hill, and on the southern by the wooded heights of Hardwick Hall. At the top end of the valley there are the houses outside the town wall; at the outlet of the valley lies the river, but severed from the site by the railway, which crosses the valley on a high embankment, and by the Town Meads, now the shipbuilding yard. Down the centre of this valley there was an old road extending halfway down, and beyond that a footpath leading to an archway under the railway. The level at the arch under the railway was 54·57 ft., above Ordnance datum, and at the top end of the land 142·9, so that the authors had a fall of about 88 ft. in a length of 1,300 ft., measured along the line of old road and footpath down the centre of the land. On the Port Wall side the highest point was 160·44, and on the Hardwick Hall side 164·8 ft. above O.D., the ground falling very sharply towards the centre. The central road, called Hardwick Avenue, 36 ft. wide, having been tentatively fixed, the side streets were arranged at such distances apart as would give space for two houses and their gardens—about 155 to 190 ft. The general direction of the side streets follows the natural contours of the land. The widths of the streets are 24 ft. and 36 ft. with 14-ft. and 24-ft. carriageways respectively between the curbs. Three open spaces were proposed: one in the centre of the site, to be planted with trees round it, and to be provided with benches, as a village green; one at the top end, where the site is fairly level, intended for bowling greens or tennis courts; and one—the largest—at the lower end, for general recreation ground. Part of this is below the level of the railway, and is being filled up to that level. The scheme proposes about ten houses to the acre. The garden ground to each cottage varies in extent. For the supply of coals, the removal of waste and to give access to the back doors, by which the working man enters after the day's work, back lanes have been formed. In the central road—Hardwick Avenue—the old 9-in. pipe sewer remains. In other streets 6-in. sewers are used, except on one side where a 9-in. pipe sewer was laid for special reasons.

"THE HOUSES GENERALLY.

"In a scheme such as this, designed for various classes of workmen, labourers, skilled tradesmen, foremen and clerical staff in a shipyard, there must be some variety in the extent and quality of the accommodation. The smallest house has a living room or kitchen of about 168 sq. ft. area, three bedrooms, a scullery with bath, a fuel store, w.c. and larder. The largest so far designed has kitchen, parlour, dining room, four bedrooms, bath with hot and cold water, scullery and offices. It would be economical in many ways—in the architect's labour, for instance—to use a few types and repeat them all over, but results would probably be disappointing from the sameness of the designs. The British working man is by no means indifferent to the value of a house of some individuality and a pleasing appearance, though he often says that all *he* cares for is good accommodation. He is not enamoured of the streets of houses in which the only means of identifying his dwelling-place is by the number on the door. In our case, the discussion of *pros* and *cons* for type-plans was useless, as the hilly site made it impossible to do much in the way of standard plans. Each block of cottages had to be planned to suit very uneven sites, and there was also the aspect and prospect to consider. All around are splendid prospects of the neighbouring hills, and as each row of houses rises, terrace fashion one above the other, there was strong reason for considering this question of prospect. As to aspect, sun is so important to us in our island climate that we made great efforts to get sunny rooms. No architect would willingly put houses of the same plan on both sides of a street running east and west. . . .

"All the accommodation required is provided within the walls of the house; there are no outhouses.

"SOME POINTS IN THE PLANS.

"The front doors open into a small porch; in the larger houses into a staircase hall. From this the doors of the principal rooms open out, and the stairs ascend. At the backs of the houses there is an open porch in which we place the doors to the scullery, the w.c., and the fuel store. This arrangement saved us from the appearance of three doors in the back elevation of a small house, and from a great difficulty in making a satisfactory back elevation. It shields the w.c. door; it forms a convenient place for boot-brushing under cover; and it enables the scullery door to be left open on washing day or any day, even in bad weather. In a few cases in the smaller houses the stair opens from the living room instead of out of the front porch. . . . Where conditions were favourable windows were put in two walls of rooms. A room with windows in two walls is always more cheerful, and is better lighted with smaller window area than by a window in one wall. Every house has a bath; in one or two cases the bath is in the scullery, but in nearly all the houses it is in a separate room. The hot water is taken from the copper close by by hand. The first cost, and cost of maintenance of the plumber's work in a hot-water service in workmen's houses, was considered too great, and in practice this method of supply seems to give satisfaction. Sometimes the copper is in the scullery, sometimes in the bathroom which opens off the scullery. Each arrangement has its own advocates. In the larger houses for foremen, who are more careful and more responsible tenants, the bathroom is upstairs, with a proper hot-water service to the bath, sink, and lavatory basin. The coppers are independent without brick-setting. The kitchen ranges were some of the Yorkshire range type, and some of the open-and-close fire type. The thresholds are in all cases set 2 in. above the floor line to allow for doormat. The ground floor ceilings are made 8 ft. in the clear as a minimum. The bedrooms upstairs are also 8 ft. at least in the greater part of the room. . . . .

"MATERIALS AND CONSTRUCTION

"The external walls are built of two thicknesses of 4-in. thick solid plain concrete blocks with a 3-in. cavity, with the usual iron ties. The blocks were made in Winget block-making machines, of which we had two on the works. In the first cottages built, the blocks were each 32 in. long, 9 in. high, and 4 in. on bed, except the closers. At the corners, L-shaped blocks were used. It was found that the workmen objected to handling such heavy blocks, and in later houses the length was cut down to 16 in. The appearance of the shorter blocks is not so good, and the walls are not so strong to resist settlements, though so far we have had no settlements to contend with.

These hollow walls were built direct on the foundations, without footing courses The foundations were of cement concrete, 9 in. thick and 2 ft. wide. The lintels had steel reinforcement varying in amount with the span. . . .

" The concrete blocks were made on the site, of local stone chippings and sand, and we were confident, from experience with other such blocks in cottages in the West Country, that the appearance would be better than that of a wall of large pressed bricks. The usual cold grey textureless surface of concrete walling arises from the floating of the finer materials to the face of the wall. Here we used a dry mixture of concrete, so that we did not have that result. Then the face-mould—a cast-iron plate—had groovings in it, giving what is called in masonry a droved surface to the finished block, which has nothing of the dull appearance already mentioned. There was another advantage in this droved face ; we had no surface crazing which occurs in the smooth face when that smooth face is due to the floating of the richer and finer materials to the surface. The many joints in the wall give it a power of expanding and contracting without developing *visible* cracks. In our climate the nights are always cool, and concrete does not get heated all through, so that there is comparatively little temperature effect ; that little is taken up by invisible cracks in the joints.

" The partition walls were also made of the same blocks, without, of course, the droved face. The thickness was 4 in. for bearing partitions, and 2½ in. for the small partitions dividing sculleries, larders, fuel stores, etc. No plastering was done on the walls of these sculleries and domestic offices on the ground floor. The internal effect is like dressed stone. The saving in first cost of plastering is considerable, and there are no recurring bills for repairs to plastering which absorb so much of the rent.

" The roofs are covered with sand-faced tiles varied in colour. It was found that the extra cost of using these tiles instead of the cold blue Welsh slate was but little, and when you consider the æsthetic effect of the red-tiled roofs and grey walls, as compared with the blue slate and grey walls, there can be no question that the small extra cost was well spent.

" The valleys are all swept valleys in tiles and the ridges plane roll tiles such as you see in all the old cottages in the districts where tile roofs are used. The few small valley-gutters were laid in Ledkore, and the junctions with the vertical faces of chimneys, etc., were made in cement. The workmen who did the tiling were skilled men who took a pride in their work, and it is pleasant to record that, so far, there has not been a single case of leakage through either roofs or walls. The floors and roofs were designed to be of ordinary timber construction, and the first thirty-one houses were so built. In later cottages we could not get permits to use imported timber for floor joists or floor boards, and, after a good deal of consideration, decided to use floors of hollow brick, with flat steel tension bars, for the first floors. These floors were formed on centering in the usual way. The ground floors throughout are of cement concrete, covered in the domestic offices with cement and all the living-rooms, parlours and bedrooms with Wilfley flooring. Where the upper floors are of hollow brick, they also are finished with Wilfley floors. The chimney stacks are in red sand-faced brick. Picture mouldings are provided in all living-rooms and parlours.

" We may here mention that the doors, windows, stairs and chimneys, etc., were standardised, a limited number of types being used. The first fifteen houses cost about £450 each, exclusive of any proportion of roads, sewerage, garden formation or fences. The second fifteen cost about £530 each. We cannot determine the cost per house of the remainder, as the cost of wages, etc., has risen a good deal, and forms a very important element in the total . . . . .

" Before closing, it may be well to explain why reinforced concrete, which has so large a place in the public mind, was not used here, especially as the architects of the scheme have had so much to do with reinforced concrete work elsewhere. The reason is that knowledge and experience of reinforced concrete teaches its true use and its limitations. It is not a desirable material for external walls ; it is expensive, almost certain to result in minute but disfiguring cracks when used for walls, and has not a pleasing surface as it comes from the moulds. It is too expensive for interior partitions. For floors it is not only expensive, but it communicates sound from room to room readily. It requires generally beams to support the floors and thus brings loads at points, not always in convenient places ; it affords no facilities for fixing gas pipes, etc. There have been suggestions made for its use in roofs. The flat roof—the most economical form for this material—is not suitable for cottage roofs in this country. It is cold, and its appearance is against it where tradition has so much to do with our ideas of the beautiful. Of course, we use trusses of reinforced concrete in factories where there are many repeats, of a standard pattern, but that condition does not obtain in cottage building on such a site as this. We have not yet solved the problem of making cottage rafters in it. Many capable minds are at work on the matter, and times may yet bring us enlightenment and good ideas.

"STYLE OF ARCHITECTURE.

"The days are happily gone when we were asked, 'In what style is this building?' Architecture is not a thing of mode; it is false to itself if it tricks out its works in the garments of another age. The Early English church, the Tudor cottage, the Jacobean house, as built in Victorian days, were essentially false, and foredoomed to failure. The controlling factor in the design of any building is the plan, and not even the wildest enthusiast would dream of reverting to the plan of the medieval house or cottage. If we have higher ideals of home life and correspondingly higher and more complex requirements in planning, these must have the most important effect on the exterior—on the *style* of the design. Our task is to give the needs and the ideals of our time embodiment in our buildings—the best expression in the language of our day. *Our* language is based on the language of William of Wykeham, of John Thorpe, and of our forebears; but it would be ridiculous affection to use their speech or strut about in their clothes. So these cottages are simply cottages of this time. We are given the needs of a home for a labourer or artisan or a foreman, and we have so to contrive our design that he may be satisfied, and that the decencies and the graces of life are open to him. To the material requirements of health and bodily comfort and convenience we have to add such pleasures as can be got from the eye, through which we appeal to the mind and heart, variety in plan and appearance; proportion, mass, and grouping, and all those elements of design which are as undefinable as the pleasing elements in poetry or music. . . ."

DISCUSSION.

Mr. Raymond Unwin, in proposing a vote of thanks, said the authors had given them a demonstration of the absolute necessity of having an architect in charge of every housing scheme. He hoped that the example which had been set at Chepstow would be widely followed by those who would have to take a part in the great rehousing schemes all over the country which would form such an important part in reconstruction. Mr. Dunn had told them that he had not had a single leakage in walls or roofs. That was certainly a triumph in concrete construction, which a good many people who had tried it were not able to claim. It would be interesting if Mr. Dunn could tell them whether he used the majority of his blocks practically green from the machine, a few days old, or whether they were allowed time to mature. He would also like to know what mortar or cement he used. With regard to the hot water question he thought they were in a transition period. There was a great demand among the working women of the country for labour-saving appliances in house work, and he thought it probable that developments would take place along the lines of better systems for heating water and more economical systems for using fuel for cooking and heating purposes.

Professor Adshead seconded the motion, and said it was particularly interesting to him to note the method of construction adopted at Chepstow. He thought that in future they would get a concrete cottage that would not absorb quite so much material and be what perhaps Mr. Dunn himself might describe as more scientific if erected in large numbers where the right material and workmanship were available.

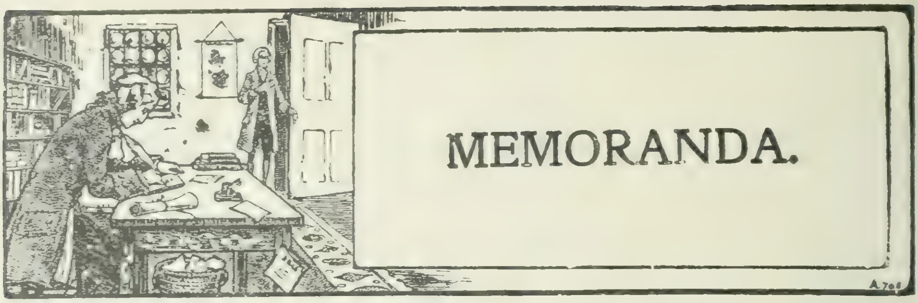
Mr. A. J. Pitcher said that if architects were going to study cottage building as they had done he thought they might legitimately ask that they had a fair share of the cottages that were going to be put up or subsidised by the Government. At the present time the proposition seemed to be that architects would not be called in to build those cottages. An important question that would have to be faced was the cost. Mr. Dunn had told them how the second fifteen cottages had cost about £80 more each than the first fifteen, and it would be very interesting to know the cost of the remainder. He was afraid that they would not get the ordinary builder for some years to come to set about erecting three-bedroom cottages at the cost mentioned by Mr. Dunn, so that apparently the State would have to come in with a subsidy. He thought it was of the greatest importance that architects as a whole should endeavour to get control of these Government and municipal schemes and carry them out on the lines that Mr. Dunn had initiated at Chepstow.

Mr. Herbert Baker, in supporting the vote, asked Mr. Dunn whether he had practically worked out the question of a communal hot water supply for the cottages he had erected.

The President, in putting the vote to the meeting, said a considerable amount of discussion was going on at the present moment as to whether concrete walls or brick walls were cheaper or better, and one was always anxious to get information on that point. A very little economy was worth making, on account of the enormous amount of repetition which they got in those houses, and, as far as he had been able to get information on the subject at the present time, there was nothing cheaper than ordinary brickwork under ordinary conditions. There were some manufacturers of concrete blocks who said that they were very much cheaper, but, as far as he had been able to ascertain, this was not the case, given a fairly easy supply of suitable bricks. With regard to the size of the blocks, where they were using concrete blocks, the larger they could cast them within the limits of easy handling, the more economical the use of the blocks would be. There was one point which occurred to almost anyone, and that was that if they had large blocks, the appearance of the cottages would suffer, providing the joints showed. He should have thought it would have been necessary to have coloured the blocks with something in the nature of cement or lime-whiting, in order to conceal the joints. He had had a good deal to do lately with the question of the provision of baths in cottages, and the conclusion that apparently had been come to was that a separate bathroom was a practical necessity, even in the smallest cottage. The ordinary arrangement which had been adopted hitherto, of putting the bath in the scullery, seemed to be objected to on the ground that there was no privacy. It was understood that in most of the cottages which were going to be built almost at once, a separate bathroom would be more or less insisted on. On the question of the employment of architects in these housing schemes which would shortly be put in hand, the Institute had taken every possible action, in order to insist upon that method of procedure. In all the negotiations which they had had with the Local Government Board in connection with the competitions recently held, they had put forward that consideration in the strongest possible way, and they were now issuing a circular to local authorities, in the same sense, stating that it would be to their interests to employ an independent architect in every case, and he thought that course was being taken more largely than it had been hitherto. It seemed to be recognised that in this very simple problem of housing, the greatest skill and the greatest experience was really necessary, because they were simple. It was realised that because they were simple they were, in the same proportion, so much more difficult, and if they were going to get anything better than the rows of hovels which they had been used to seeing, it must call for the greatest skill, experience and judgment of the architect. For that reason they hoped and expected that architects would be employed in the majority of cases where these schemes were going to be put forward. He might say that the Local Government Board had given them the assurance that, although they were not in a position to insist upon that being done, still that was their intention, and that was the course they hoped would be followed by local authorities.

The Lecturer's Reply.

Mr. Dunn, in a brief reply, said that the concrete blocks were usually used not less than a week old, but generally they were older. They were set with cement mortar, and the joints were made to show. If they were to lime-white the blocks, as suggested by the President, they would lose their charm of colour, and it would mean additional expense. Mr. Baker asked about communal hot water supply. He (Mr. Dunn) had not as yet found any method of doing that on a practical scale, especially on such a site as the one they had to deal with at Chepstow. The loss of heat on passing from the central station would be great, and the cost would also be very great, and on a hilly site especially there would be very great difficulties, on account of the enormous pressure that would be needed.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome. —ED.

The Concrete Institute.—The first meeting of the session 1918-19 took place on November 28th, when the newly elected President, Mr. H. D. Searles-Wood, F.R.I.B.A., delivered his inaugural address.

Up to the time of going to press we have not succeeded in obtaining a full report of the Address, but we note that it included two useful reports of the Sub-Committees of the Institute.

One of these reports dealt with the relation that should exist between architects and specialist engineers in the conduct of work. The other report comprised particulars regarding the Examinations of the Institute.

The President mentioned that the Institute's report on the possible application of concrete as a substitute for timber would shortly be made more freely available, which is a matter of congratulation.

Generally speaking the address summarised the current work of the Institute.

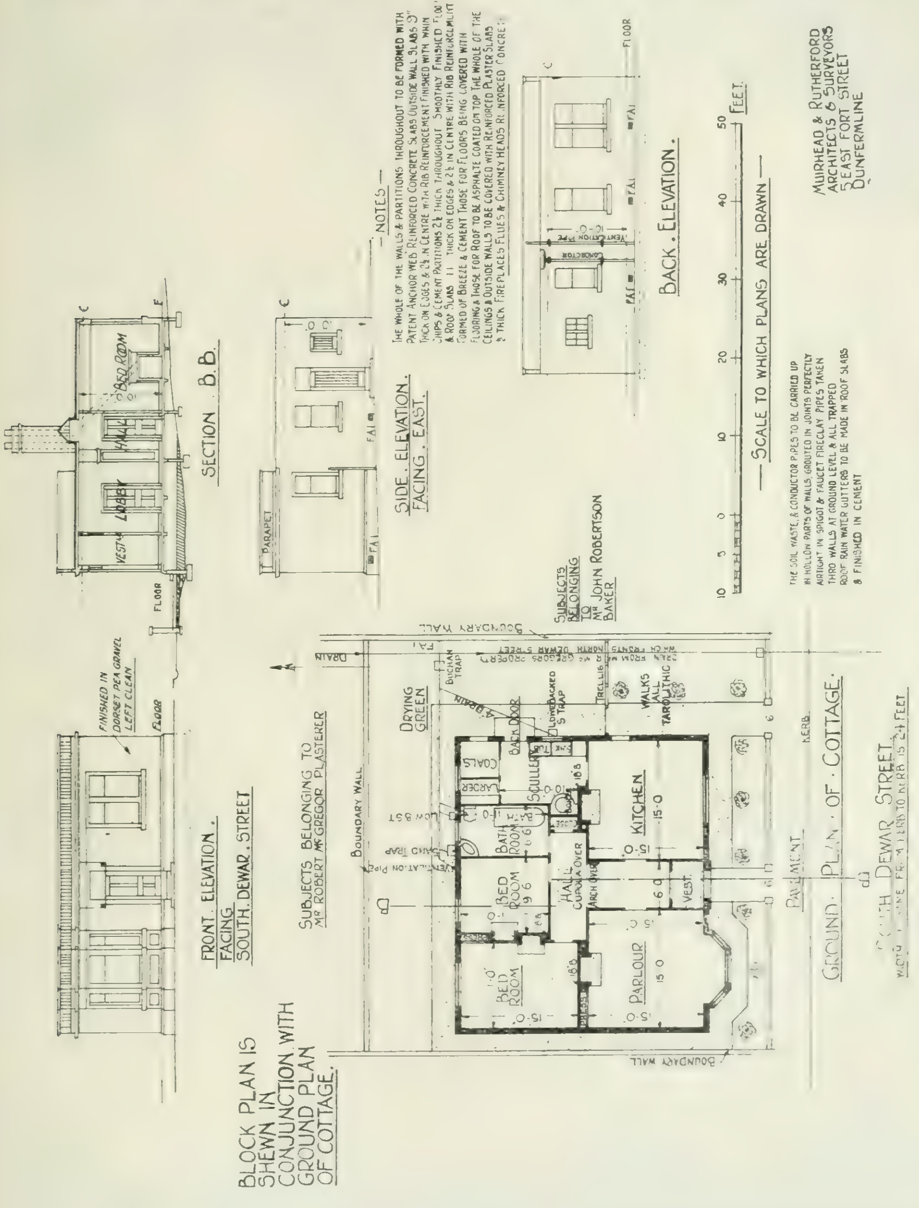
The vote of thanks was proposed by Mr. F. E. Wentworth-Sheilds and seconded by Mr. E. S. Andrews.

The Royal Institute of British Architects.—At the opening of the Winter Session the President, Mr. Henry T. Hare, read an interesting address, and in the course of his paper made reference to the competition, instituted at the instance of the Local Government Board, for designs for houses for the working classes. We extract the following paragraph from the paper which appears to be of special interest in connection with the Housing question:—

"Following the competition we have suggested to the Local Government Board the desirability of actually erecting a small number of these cottages in a readily accessible position near London and furnishing some of them ready for occupation, so that they may be inspected and criticised by all those who are interested and serve as a general guide to those who are about to promote housing schemes. It is felt that by no other means can a really satisfactory solution be arrived at, for mere drawings cannot convey the same impression as the actual object in being. I am happy to say that this suggestion has been accepted, and we are now considering the details of carrying out the project with the least possible delay."

British Reconstruction Commission for Belgium.—It is announced that a British official mission has gone to Belgium to report upon the need for reconstruction. The whole matter of reconstruction, it is understood, is being dealt with by the Inter-Allied Reconstruction Commission and a special British Department known as the Belgian Trade and Reconstruction section of the Department of Overseas Trade The mission consists of Sir Arthur Steel Maitland, Head of the Department of Overseas Trade; Sir E. Wildbore Smith, chairman of the International Commission; Sir Herbert Llewellyn Smith, of the Board of Trade; Mr. Keynes, of the Treasury; Mr. M. N. Kearnew, Secretary of the International Commission, and officer-in-charge of the Belgian Reconstruction Commission; Major Pheunis, Belgian delegate; and Major Gunning, American delegate. It will be the business of the mission to make a tour of inspection of the devastated areas, and report on what is wanted.

Experimental Cottage at Dunfermline.—Some time ago delegates from the Fifeshire District Executive of the Scottish Labour Housing Association and the Dunfermline Trades Council inspected a new form of concrete cottage erected by Mr. Walter Wilson, Inspector of Works, Dunfermline, to his own plans and specifications. By the courtesy of Messrs. Muirhead & Rutherford, architects, acting on Mr. Wilson's behalf, we are able to present a plan of this cottage as erected. It is all constructed in the designer's patent anchor web reinforced concrete.


FRONT . ELEVATION . FACING SOUTH . DEWAR . STREET
FINISHED IN DORSET PEA GRAVEL LEFT CLEAN
FLOOR
SECTION B.B.
VEST.
LOBBY
HALL
BED ROOM
SIDE . ELEVATION . FACING . EAST .
PARAPET
F.A.L.
– NOTES –
THE WHOLE OF THE WALLS & PARTITIONS THROUGHOUT TO BE FORMED WITH PATENT ANCHOR WEB REINFORCED CONCRETE SLABS OUTSIDE WALL SLABS 3" THICK ON EDGES & 2½ IN CENTRE WITH RIB REINFORCEMENT FINISHED WITH WHIN CHIPS & CEMENT PARTITIONS 2½ THICK THROUGHOUT SMOOTHLY FINISHED FLOOR & ROOF SLABS 11 THICK ON EDGES & 2½ IN CENTRE WITH RIB REINFORCEMENT FORMED OF BREEZE & CEMENT THOSE FOR FLOORS BEING COVERED WITH FLOORING & THOSE FOR ROOF TO BE ASPHALTE COATED ON TOP THE WHOLE OF THE CEILINGS & OUTSIDE WALLS TO BE COVERED WITH REINFORCED PLASTER SLABS ¾ THICK FIREPLACES FLUES & CHIMNEY HEADS REINFORCED CONCRETE
BACK . ELEVATION .
FLOOR
VENTILATION PIPE
CONDUCTOR
SCALE TO WHICH PLANS ARE DRAWN
10 5 0 10 20 30 40 50 FEET.
MUIRHEAD & RUTHERFORD ARCHITECTS & SURVEYORS 5 EAST PORT STREET DUNFERMLINE
THE SOIL WASTE & CONDUCTOR PIPES TO BE CARRIED UP IN HOLLOW PARTS OF WALLS, GROUTED IN JOINTS PERFECTLY AIRTIGHT IN SPIGOT & FAUCET FIRECLAY PIPES TAKEN THRO WALLS AT GROUND LEVEL & ALL TRAPPED ROOF RAIN WATER GUTTERS TO BE MADE IN ROOF SLABS & FINISHED IN CEMENT
SUBJECTS BELONGING TO MR JOHN ROBERTSON BAKER
BOUNDARY WALL
DRAIN
DRAIN FROM MR MC GREGORS PROPERTY WHICH FRONTS NORTH DEWAR STREET
BUCHAN TRAP
DRYING GREEN
BACK DOOR
LOWBACKED S TRAP
WALKS ALL TAROLITHIC
SUBJECTS BELONGING TO MR ROBERT MC GREGOR PLASTERER
BOUNDARY WALL
VENTILATION PIPE
COALS
LARDER
SCULLERY
BATH ROOM
BED ROOM
HALL
CUPOLA OVER
ARCH OVER
KITCHEN 15-0 15-0
VEST.
PARLOUR 15-0 15-0
BED ROOM 15-0
KERB
PAVEMENT
GROUND . PLAN . OF . COTTAGE .
SOUTH DEWAR STREET
BLOCK PLAN IS SHEWN IN CONJUNCTION WITH GROUND PLAN OF COTTAGE.

Plan, Section and Elevations of Reinforced Concrete Cottage erected at Dunfermline.

Reinforced Concrete Cistern Cap.—According to *Popular Mechanics* a cistern cap can easily be made of reinforced concrete. A cover of this material has the advantage

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that it will withstand the effects of the elements indefinitely and that it will not foul the water.

The procedure is as follows : Fit planks over the opening of the cistern. Then lay a sheet of heavy paper over these boards. This prevents the concrete from sticking to the wall or leaking through the cracks. Arrange the form boards, which should be 4 or 5 in. high around the outside, and support them in position with stakes. Then bend a strip of sheet iron into a hollow cylinder of sufficient diameter to admit the pump cylinder. Set this form in the centre to provide an opening for the pump. Place heavy iron rods for reinforcing, in the form, and fill the form with concrete.

Before the concrete has set push into it vertically, down to the wooden cover, four cylindrical sticks of wood. These should be located to correspond with the bolt holes in the pump base. After the concrete has set remove the form boards and bore out the cylindrical wooden rods.

Separating Concrete Aggregate into Four Sizes.—Concrete aggregate for use in the Lower Otay dam, now being rebuilt for the San Diego water-supply system, is being separated into four sizes—2½, 1½, ¾, and ¼ in. This is being done so that the ideal proportioning, determined by careful tests, may be secured. The sizing is obtained without increase in cost, trials having shown that with a crusher properly set and the proper length of each mesh in the screen, the run of crusher gives the proper amount of each size. In other words, there is no wastage of material. The bins are on the side of the cañon, and the four chutes, one from each bin, are so located that they are manipulated by one man. Construction work is being carried on under the direction of H. N. Savage, consulting engineer for the city of San Diego.—*Engineering News-Record.*

Boston.—*River Works*—The Roads and Bridges Committee of the Holland C.C. has approved a plan and specification for repairing, in reinforced concrete, the river bank on the south end main road at Boston, and has ordered the work to be carried out if approved by the Boston Harbour Trust and Witham Outfall Board.

Midland Junior Gas Association.—*Concrete Piles.*—At the opening meeting of the new session of this association, the newly elected President, Mr. T. H. Poulson, devoted a large portion of his address to the subject of pile-driving at Stafford, to provide stable foundations for the buildings at the Stafford Gasworks, which are contiguous to the River Stour. He dealt first of all with the substrata on which the works are erected, and then described the three types of piles used (as follows) to prevent subsidence :—

1. (*a*) Pitch pine. Length, 26 ft. to 53 ft. ; cross section, 10 in. square.
   (*b*) Pitch pine. Length, 35 ft. to 85 ft. ; cross section, 12 in. square.
2. Moulded reinforced concrete, "B.R.C." type. Length, 26 ft. to 37 ft. ; cross section, 12 in. square.
3. Stewarts' "C.P." concrete tube system. Length, 42 ft. to 55 ft. ; diameter, 16 in.

They were used as follows :—

1. (*a*) In the old portion of the works in the foundations of horizontal retorts and chimney, condensers, scrubbers, purifiers, and railway bridge. (*b*) In the newer portions under the carburetted water-gas plant and buildings, relief holder, oil-storage tanks, sulphate plant and buildings, boiler-house and chimney, and the tar storage tanks.—2. In the foundations of the 1¼ million cu. ft. per day vertical retort installation and coke plant.—3. Under the scrubber-washer, benzol plant, and the oil and acid storage tanks.

After describing the preparation of the various piles, and the pile-driving apparatus employed, he detailed the operations for framing and driving the piles, the method of lengthening them, and the preparation of the foundations above the piles. He then dealt in detail with Stewarts' "C.P." concrete piles, in which system, cylindrical steel tubes are driven into the ground to the required set, filled with concrete, and withdrawn, leaving a column of concrete, which constitutes the pile, in the ground. Thus, there is no pile-driving as such, no damage to piles by splitting or breaking, no lengthening required, and little cutting.

He mentioned that no subsidence has been observed in buildings erected on piles carrying the following load per pile :—

	Tons.
Pitch pine, 12 in. square	16
Reinforced concrete, "B.R.C." type	37
Stewarts' "C.P." tube system	33

Dealing with the advantages of concrete over timber piles, he stated these as being :—

1. The material used in their manufacture can be obtained in any locality.
2. Reliability, due to even consistency of material throughout.
3. They do not rot—age, within limits, increases their strength.
4. They carry a greater load ; therefore fewer piles are required.
5. It is not necessary to drive them below land water-level ; consequently much excavation, concrete, and brickwork footings are saved.
6. Foundations immediately above the concrete piles can be united with piles, and not merely laid on the top, as in the case of timber foundations.

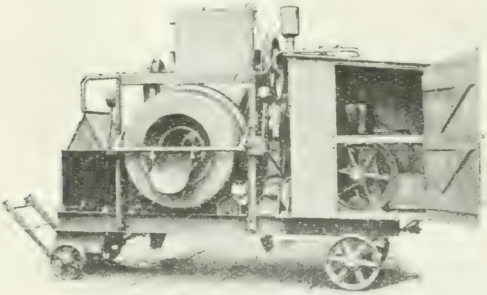
Finishing his remarks upon piles, he commended the subject of concrete piling as being worthy of the consideration of engineers who are erecting large buildings on ground which necessitates deep excavation to obtain a foundation, as it will be found in many cases to be the less costly method.

TRADE NOTE.

We hear that an imposing fifteenth-century building—St. Nicholas' Chapel, King's Lynn—has been seriously affected with dry rot in the wood flooring of the nave. It became necessary for the floor to be entirely taken out and replaced at a total cost of about £500, for there was danger that the remarkable roof carvings might become infected with the floating spores.

The authorities have taken precaution against a recurrence of the trouble, which was caused by rising dampness, by waterproofing the concrete under the new paving blocks with the powder " Pudlo "—a product manufactured in this old-world town.

The British Reinforced Concrete Engineering Co. have just issued a most useful Sheet of Tables for the use of engineers and architects when specifying the B.R.C. Fabric Reinforcements for floor slabs. The tables show the size of fabric to be used for different types of floors over various spans. They are for floors continuous over a number of spans, but may also be used for end spans and freely supported spans. Copies of this Sheet of Tables can be obtained from the above-named Company at their offices, 1, Dickinson Street, Manchester.



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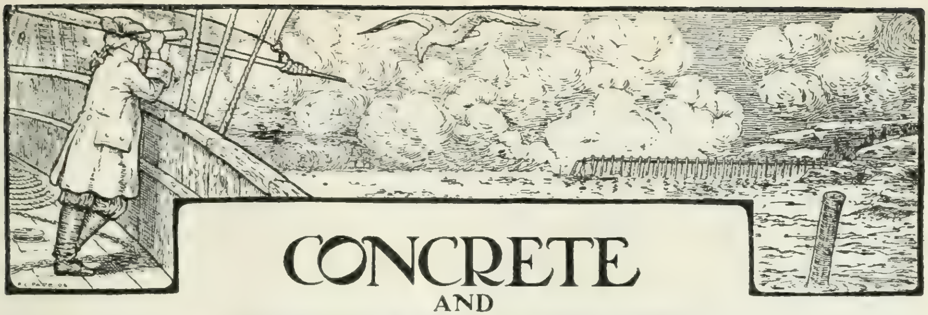


CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

"CONCRETE SHIPBUILDING"

A Monthly Supplement

Issued Free to Subscribers NOVEMBER, 1918 *Single Copies 1/-*

REINFORCED CONCRETE SHIPS, BARGES, AND PONTOONS.

By ALFRED B. SEARLE.

The present supplement is the first of a series of supplements we propose to publish giving a general review on the subject of concrete shipbuilding. In addition we hope in each number to include illustrations and particulars regarding current activities in this particular, as far as we are able to obtain and publish such information. It is hoped that these supplements will prove of use and interest to all those who are engaged in one branch or another of this particular form of the shipbuilding industry.—ED.

CHAPTER I.

THE NEED FOR A NEW MATERIAL.

AMONGST many materials which have been used for building ships, there is none which appears to the unimaginative mind to be so unsuitable as that particular kind of artificial stone known as concrete. Everyone is accustomed to think that vessels which are intended to float on water must be made of a material which is " lighter " than the water itself, whereas stone of all kinds is obviously much " heavier." Fortunately, the use of steel in the construction of various kinds of vessels has, to some extent, prepared the minds of shipbuilders and others to accept the use of materials much heavier than water, and has reduced what would at one time have been a loud outcry of expostulation to an almost inaudible murmur. Moreover, many shipbuilders have recognised for ten years or more the valuable properties of fine concrete as a protective agent and preservative, and have used it extensively for covering plating, rivet heads, floors and keelsons, and even for treating the interior of double bottoms, in the bilges and watercourses, and generally where water or rubbish is likely to accumulate. They have also used it extensively for repairs—particularly for stopping leaks—and some captains make a practice of carrying cement and sand with them for this purpose.

Thanks to the propaganda work of many of those interested in the use of concrete for bridges and other large and important structures on land, there is a general appreciation on the part of the public of the immense strength and durability of concrete and of the remarkable manner in which it may be used for a great variety of purposes. Consequently the proposal made a short time ago that seafaring vessels should be made of concrete was readily accepted as being worthy further attention.

The shortage of steel and wood, caused by the War and likely to continue for some years to come, together with the greatly increased transport requirements of the various Allied armies and the anticipated post-war trade requirements, necessitate the production of an enormous number of vessels of various sizes in the most rapid manner possible, and the utilisation of labour not hitherto employed in shipbuilding. Owing to the widespread occurrence of the sand, stone and gravel used in the production of concrete, the availability of Portland cement of recognised standard quality and the possibility of using forms of steel which are quickly produced with a minimum of labour, combined with the relative simplicity of construction, makes the building of concrete ships an attractive proposition at the present time.

As will be seen in succeeding pages, the use of concrete in shipbuilding is neither so new nor impracticable as some people suppose ; on the contrary, it has many advantages over other shipbuilding materials. Prominent naval architects in France, America and Great Britain have for some time been paying attention to this subject, and a number of firms are already engaged in constructing concrete ships. The relative weight of concrete is not so important a factor as was at one time supposed, and the readiness with which this material lends itself to the purpose makes it as valuable a material for shipbuilding as it has long been proved to be for other structural work.

The manner in which the need for new ships is being met by the use of reinforced concrete, together with a short summary of what has already been accomplished, is given in the following pages, and is followed by a brief outline of the materials used and the methods of construction employed. No attempt has been made to treat the subject exhaustively, as the use of reinforced concrete is still largely in an experimental stage, and developments are proceeding rapidly. Moreover, it is not in the national interest that certain details should pass out of the country ; apart from this and from any oversight, the information given is as full as possible without encroaching unduly on existing textbooks on naval architecture and reinforced concrete respectively—two subjects which, hitherto, have been kept separate—are now united in the furtherance of human welfare. Naval architects, in reading the following pages, should concentrate their attention chiefly on the applicability of reinforced concrete to their work, and should ignore the (to them rudimentary) information relating to shipbuilding in general. Readers familiar with the use and construction of reinforced concrete, on the contrary, will, it is hoped, find many useful suggestions whereby they can co-operate with shipbuilders.

The construction of concrete vessels is emphatically an industry in which co-operation is essential—at any rate, at present—so that the accumulated knowledge and experience of the shipbuilder's staff may be combined with that of the structural engineer accustomed to concrete, to the ultimate advantage of all concerned.

CHAPTER II.

A SHORT HISTORY OF CONCRETE SHIPBUILDING.

THE history of the construction of concrete vessels has not been confined to any one country or even to one continent. Commencing in France, it developed almost simultaneously in Holland, Central America, and Italy, and gradually spread to the United States, Great Britain, Germany, Norway, and Sweden, until, at the present time, it is extending into localities usually considered to be remote from civilisation.

This broad geographical development has been a great advantage as it has enabled many ideas and experiments to be tried which might not have been thought of if the construction of these vessels had been chiefly confined to any one country. The meticulously careful methods of French engineers have been followed by the boldness and enterprise of American shipbuilders, and the proverbial caution of the British has prevented mistakes and accidents which might easily have occurred if the industry had been localised among a more enthusiastic people.

The manner in which an industry has developed is often a valuable guide to those who are interested in its future, so that the following brief summary of what has already been accomplished affords a convenient basis on which further progress may be made.

So far as can be ascertained, the first concrete vessel was a rowing boat (*Fig.* 1), built and patented in 1849 by M. Lambot, of Carces, France. This boat remained in use and in good condition for about sixty years—a clear indication of the durability of concrete vessels on inland waterways. M. Lambot's work was investigated by the French Government in 1850 and favourably reported upon ; it was also shown at the Paris Exhibition in 1855, but, as often happens in the case of new inventions, it was left to private initiative to develop it, and nothing was done. M. Lambot, like many pioneers, was " before his time," yet his invention is extraordinarily interesting, because it is one of the earliest records of the use of reinforcement for concrete. Thus, from the construction of a small boat has arisen an entirely new branch of architecture and constructional engineering, the use of which has extended to almost every part of the globe. In the Netherlands, in 1887, Gebr. Picha-Stevens built a boat of reinforced concrete at Sas van Ghent, and in the same year the *Zeemeeuw* (*Fig.* 2)—a sloop with a capacity of 11 tons—was built by the Amsterdamsche Fabriek van Cement-Ijzer Werken. This boat is still in regular use, notwithstanding several collisions with large vessels and that she has been frozen in the ice each winter. Another interesting feature of the *Zeemeeuw* is her great stability. This vessel proved so satisfactory that several barges, 64 ft. by 14 ft., with a capacity of 55 tons, were soon afterwards built by this firm, and are in regular use on inland waterways. In 1890 P. P. Brannon, of Sonsonate, Salvador, built a concrete rowing boat, and

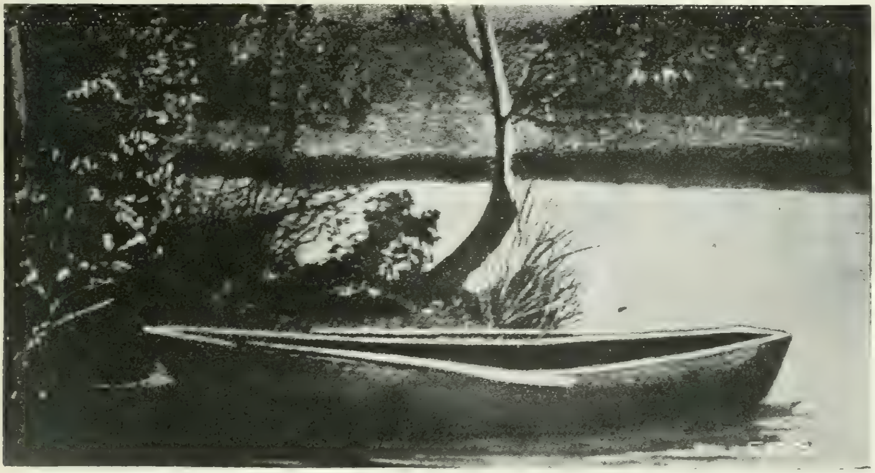


Fig. 1. The first Concrete Boat, built by M. Lambot in 1849

some time afterwards a second and much larger sailing vessel 18 ft. in length, which was in regular use for some time.

The earliest English patent for reinforced concrete vessels—that of D. Wilson, 16,530 (1887)—relates to the use of a frame of wire netting or bars or rods or strips of metal interlaced or otherwise suitably secured together, and coated with cement or concrete, either by pouring the cement or concrete into a mould of suitable size and form or plastering it on to the frame.

In 1897 a concrete pontoon, 67 ft. by 21 ft., carrying a "chalet" (*Fig.* 3), was built for the Rome Rowing Club.

In 1899 Carlo Gabellini, of Rome, commenced to build concrete barges, and by 1905 he was able to construct the *Liguria*, of 150 tons capacity, for Civita Vecchia Harbour, near Rome, on a patented system devised by him. This vessel was, in October, 1915, towed down the Tiber to the sea, also to Genoa and Savona and afterwards back again to Civita Vecchia. She has been in regular use for over twelve years.

In the following year Gabellini constructed a 150-ton barge for the Naval authorities at Spezzia, which was tested by driving her against a mass of piles and afterwards ramming her with a steel tug. The result was so satisfactory that Gabellini's boats became famous and the rapid development of concrete shipbuilding may be said to have followed from his work.

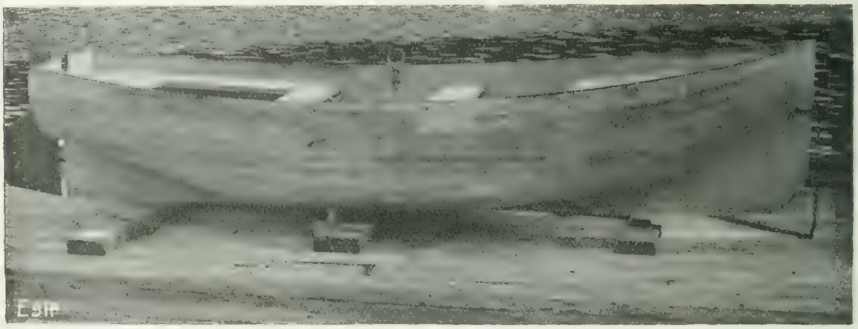


Fig. 2. The *Zeemeeuv* in 1910, when 23 years old.

A lighter built on the Hennebique system in 1906 is shown in *Fig.* 4.

By 1909 sufficient interest in the subject had been aroused for the Germans to investigate it, with the result that a 220-ton concrete lighter, 130 ft. by 20 ft. beam and 13 in. draught without ballast, was built by the Allgemeine Verbundbaugesellschaft at Frankfort-on-Main, for use on the river.

In 1909 a 10-ton boat, the *Juliana* (*Figs.* 5 *and* 6), was designed and built by A. A. Boon, of Amsterdam, around an old wooden vessel which had become unseaworthy. A netting was constructed of ¼ in. bars spaced so as to form rectangular meshes, and then filled in and covered with impervious concrete to a thickness of 4 in. It was found impossible to remove the old woodwork which had formed the centering without damaging the concrete, so the wood was cut away where this could be done conveniently, but a considerable part of it was left as an integral part of the renovated vessel, and was incorporated into the fittings. This mode of renovating old boats proved to be quite satisfactory for vessels of small dimensions, but it cannot be recommended for larger ones as the use of both wood and concrete makes the boats too heavy in proportion to their dead-weight capacity.

In the year 1910 rapid progress was made simultaneously in Holland, Canada, South America and the United States. For instance, another Dutch firm (R. Last and Sons) built a concrete motor boat for eight people, in which the shell is only ½ in. thick. This has proved quite durable, though she has only been used on inland waters and for pleasure purposes.

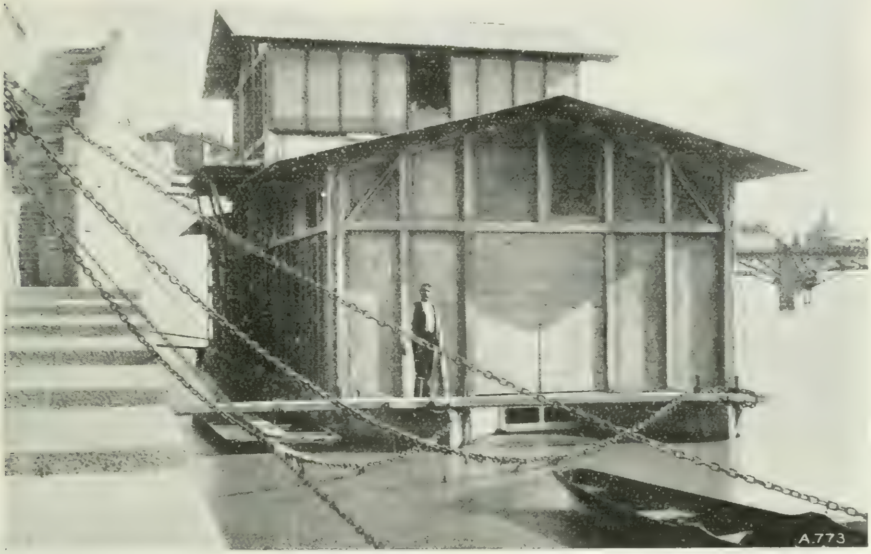


Fig. 3 Floating Chalet on Reinforced Concrete Pontoons

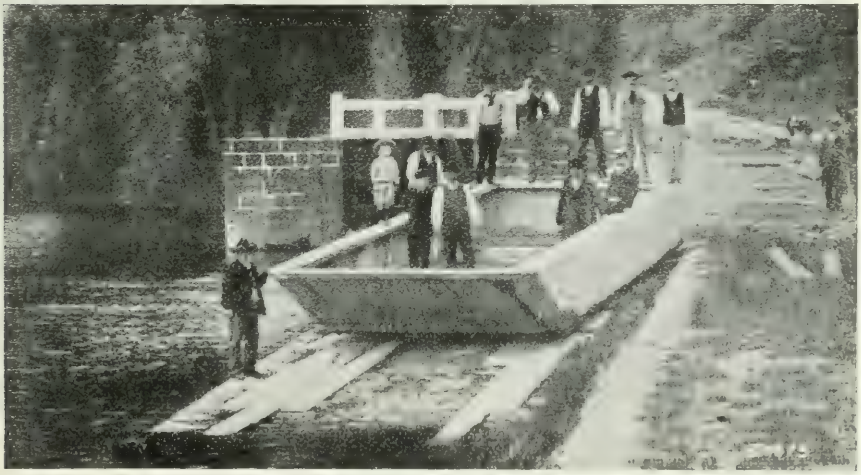


Fig. 4. An early Hennebique Lighter, built in 1906.

Mr. A. A. Boon, of Amsterdam, built the *Antoon* (*Fig.* 7)—an open lighter of 50-tons dead-weight capacity—for the removal of ashes, etc. One of several 15-ton boats used for the same purpose and a 60-ton lighter, built somewhat later by the same firm, are shown in *Figs.* 8, 9, *and* 10.

In April, 1910, Edmond Coignet completed the first of several barges for the transport of dredged materials at Bahia, in Brazil. Though the owners would have been satisfied if these barges could have been towed across the bay of Bahia in fair weather, they were able to stand much rougher usage, and were among the first *sea-going* barges whose abilities were proved by regular use.

In the same year a 525-ton concrete scow was built at San Francisco for the harbour traffic.

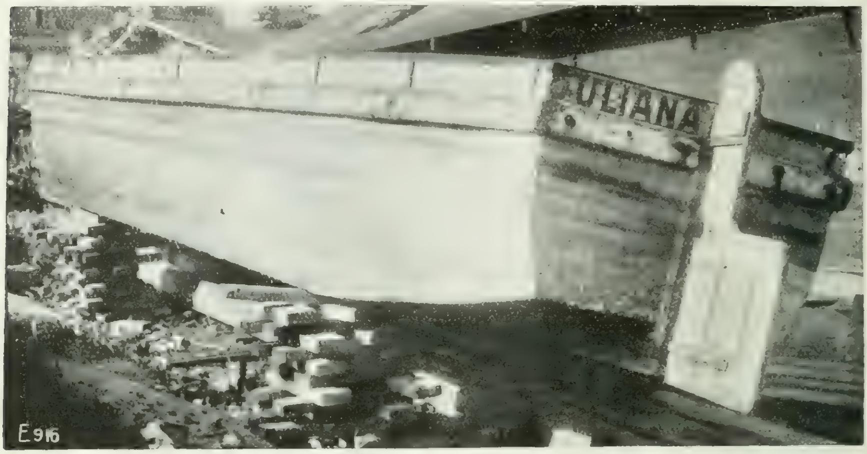


Fig. 5. The *Juliana* in 1910, after 5 years' use.

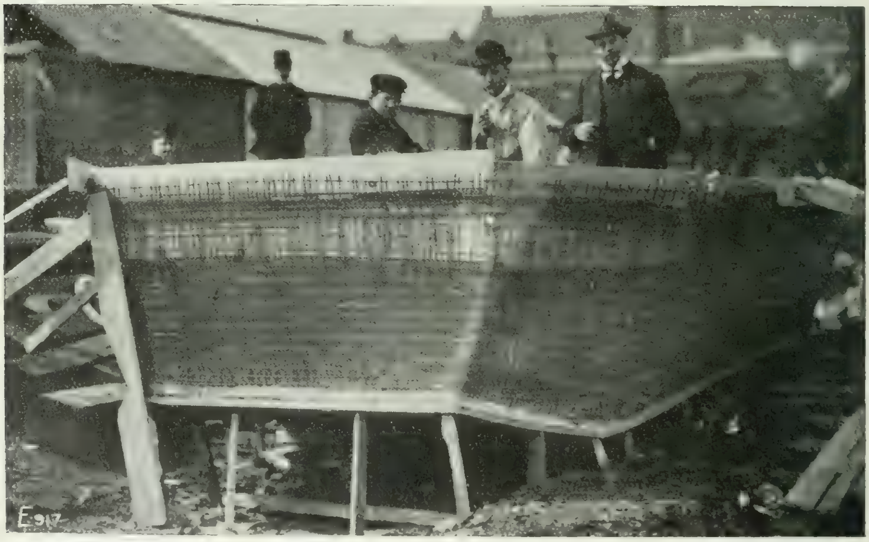


Fig. 6. The *Juliana* during construction.

A concrete barge (*Figs.* 11 *and* 12), which has been subjected to exceptionally rough treatment, was launched in November, 1910, and has ever since been in regular use for carrying stone on the Welland canal. This barge measures 80 ft. by 24 ft., with a draught of 7 ft. Carloads of stone are frequently tipped directly into it from a height of 12 ft. above deck level, yet without any serious consequences.

The concrete hull of the *Sand Witch*, a river dredger, was built on the Thames in 1910.

In 1911 the most important event in the history of concrete vessels was the construction of a number of barges on the Panama Canal. These were so successful that a number of pontoons were built for use on the same canal. This shows the great advantage of concrete as a shipbuilding material under conditions where the skilled labour and materials needed for the construction of ships of wood or steel are not available.

In 1911, also, an 80-ton concrete scow, designed by Oscar F. Lackey, then Harbour Engineer for the port of Baltimore, was built for conveying sand, gravel, and stone on Chesapeake Bay. This proved so successful that several similar vessels of the same type were built for this traffic.

In the same year the pioneer firm of concrete barge builders in Holland, which has been engaged in constructing boats of this material since 1887 (*see* p. 3), launched a barge (*Figs.* 13 *and* 14), 62 ft. long, 14 ft. wide at top, and 11 ft. at bottom, with walls about 2 in. thick. She is divided by cross walls into three parts, the middle space (37 ft. in length) being used for the 50 tons of cargo which the vessel carries. This boat weighs 36 tons. Since she was completed a number of other 50 to 60 ton barges have been built by the same firm under the superintendence of A. A. Boon, and are in regular use on the Dutch canals.

In 1911 the *Motor Boat* mentioned that a concrete motor boat, 14 ft. 8 in. long by 5 ft. 6 in. beam and 2 ft. 3 in. draught had just been launched in Germany. She was stated to travel at a speed of 3¾ miles per hour when driven by a 3-h.p. motor.

A concrete barge built in Italy in 1912, and shown in *Fig.* 15, has all its lines in the form of double curves, which involves a special arrangement of the reinforcement (described later). This boat was reported by *Il Cemento* in 1917 as " still in satisfactory service."

Another barge (*Fig.* 16) built in the same year at Mobile, Ala., U.S.A., by Luigi Volpi, on the Gabellini system, was in satisfactory use until she was washed ashore 300 ft. inland in 1916. She then sustained a small injury, which (owing to the ownership being partly American and partly Italian) has not been repaired.

In 1912 the Arundel Sand and Gravel Co., of Baltimore, built a 500-ton scow (*Fig.* 17), after designs by Oscar F. Lackey, followed shortly afterwards by two others. The owners reported in July, 1917, that the first vessel had been in use daily for more than four years for the transport of stone and gravel. The second vessel broke away in a storm and was washed ashore on a rocky promontory. A hole in the hull—the result of this storm—was repaired, and the vessel has been in regular use ever since. The third vessel is in regular use by another firm. In the period since they were built, these lighters have given no trouble with the exception of the one wreckage, and there has been no necessity to pump out the water as is always the case with wooden barges. Although these concrete barges are heavier than those built of wood the owners consider that they can be towed just as easily.

In the same year, a concrete sailing boat was built at Dresden by Johannes Lescher, and in spite of frequent groundings gave excellent service. (No information respecting it has been available since 1914.)

In 1912, also, the Yorkshire Hennebique Contracting Co., of Leeds, built a concrete pontoon, 100 ft. by 28 ft., on the Manchester Canal for carrying sludge pumps, boilers, and fuel. Its cost was low, maintenance expenses are less than on similar pontoons built of other materials and repairs can be made without dry docking.

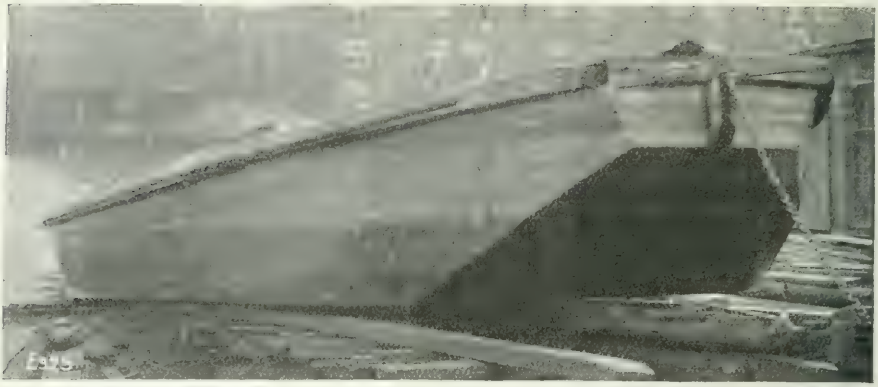


Fig. 7. The *Antoon* (built in 1910) after six years' use.

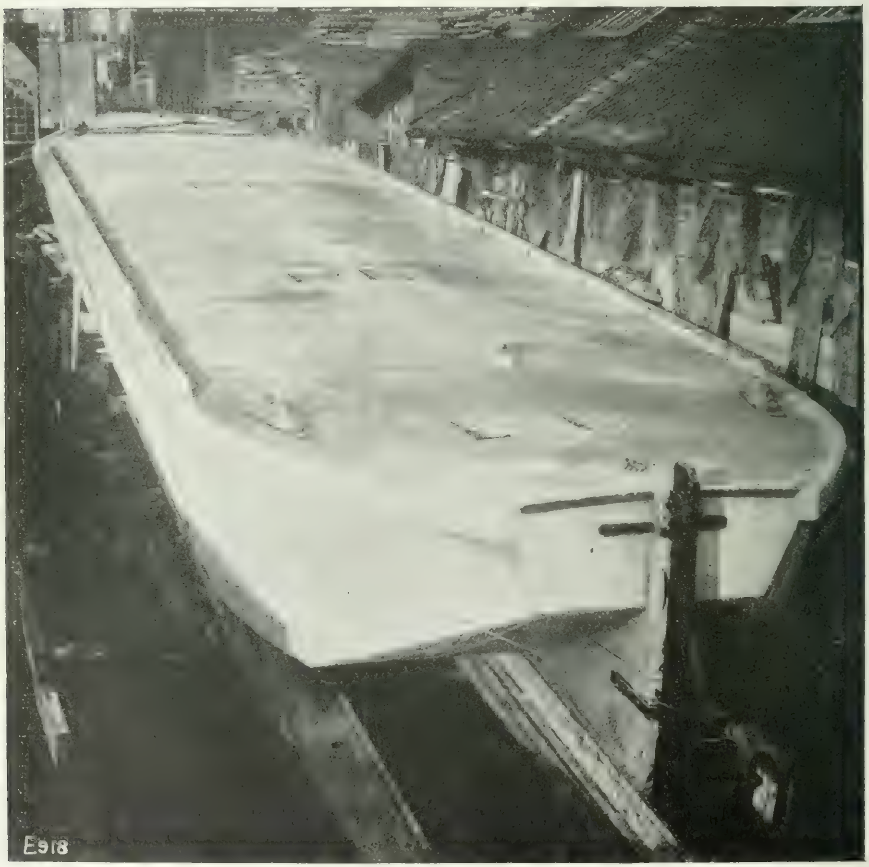


Fig. 8. 60-ton Lighter ready for launching.

In 1913, another 500-ton concrete scow was built after designs by Oscar F. Lackey, by the Furst Concrete Scow Construction Co., at Fairfield, Md., U.S.A.

In the same year, a self-propelled reinforced concrete crane pontoon, 100 ft. by 43 ft., fitted with motor and screw, was constructed at Marseilles. The crane is 33 ft. high, with an overhanging or unsupported length of 33 ft., and a load-carrying capacity of 30 tons. The pontoon has double sides to protect it against flooding should the outer wall be damaged.

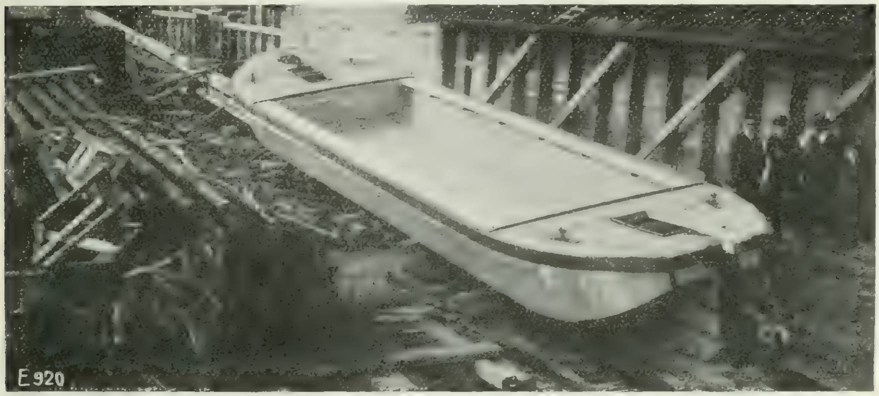


Fig. 9. Lighter for ashes and mud.

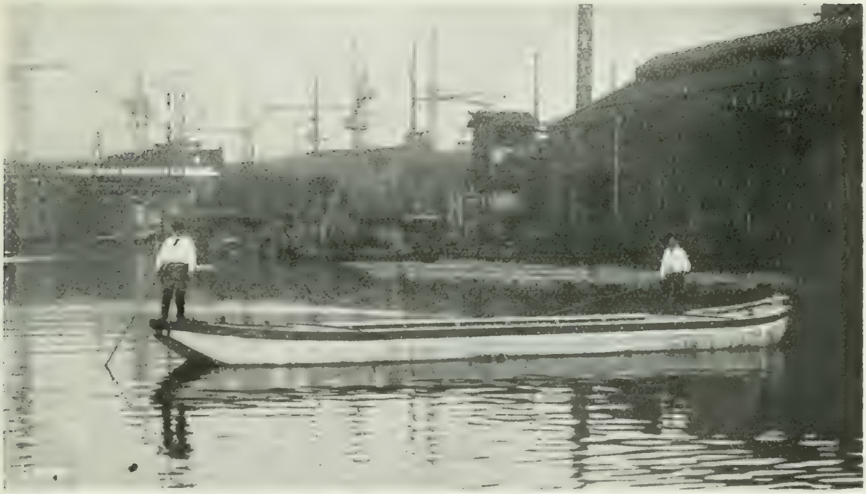


Fig. 10. A Lighter for ashes and mud.

In 1914 two more concrete pontoons for use as landing stages were built on the Panama Canal.

In the same year a 100-ft. concrete pontoon (*Fig.* 18) was built in Sydney Harbour, N.S.W., and has successfully weathered the severe storms it was built to resist.

At the same time, a concrete motor boat (*Fig.* 20), 18 ft. 6 in. by 4 ft. 6 in. by 3 ft. 2 in., was built at Dowsey, Iron River, Michigan. This boat, which is driven by a 6-h.p. engine, was in regular use until 1917, when she was taken to Chicago and presented—still in perfect condition—to the Chicago Naval Reserve for use as a practice boat.

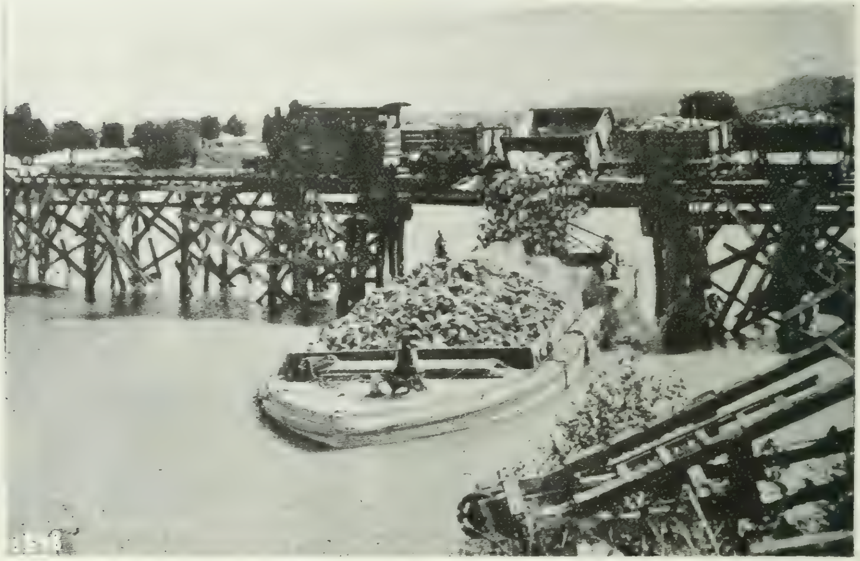


Fig. 11. The Concrete Barge *Pioneer* in use on the Welland Ship Canal.

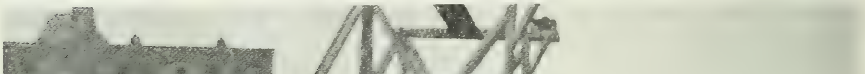


Fig 12. Another View of the Barge *Pioneer* on Welland Ship Canal.

In 1915 the Chesapeake Concrete Barge Co. built a 500-ton concrete scow of the Oscar F. Lackey pattern.

In 1916, four more concrete pontoons for use as landing stages were built on the Panama Canal. The motor cruiser *Wanderer* (*Fig.* 19) was also built in 1916 by two members of the Sabin Hill Yacht Club, Dorchester, Mass. This craft is 41 ft. over all, with a beam of 8 ft., increased at the water line to 11 ft., by means of a sponson on each side of the vessel; the sponsons also give great stability and buoyancy. The 25-h.p. engine drives the vessel at a speed of 7½ knots.

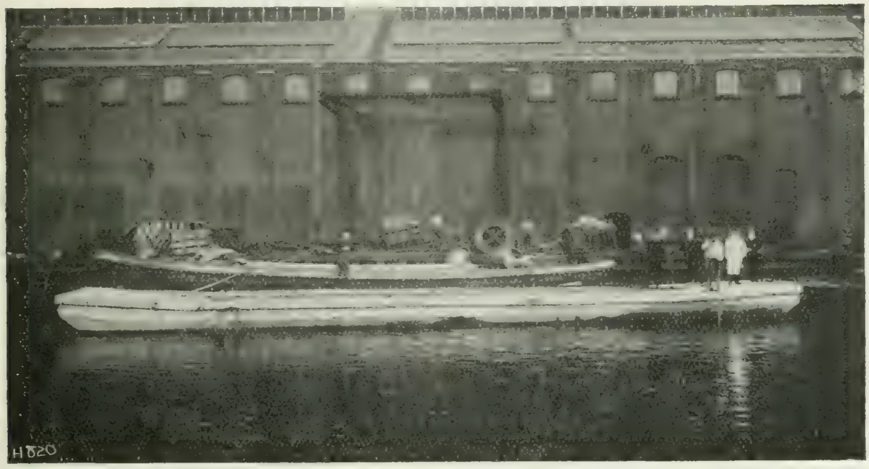


Fig. 13. Concrete Boat at Amsterdam after launching.

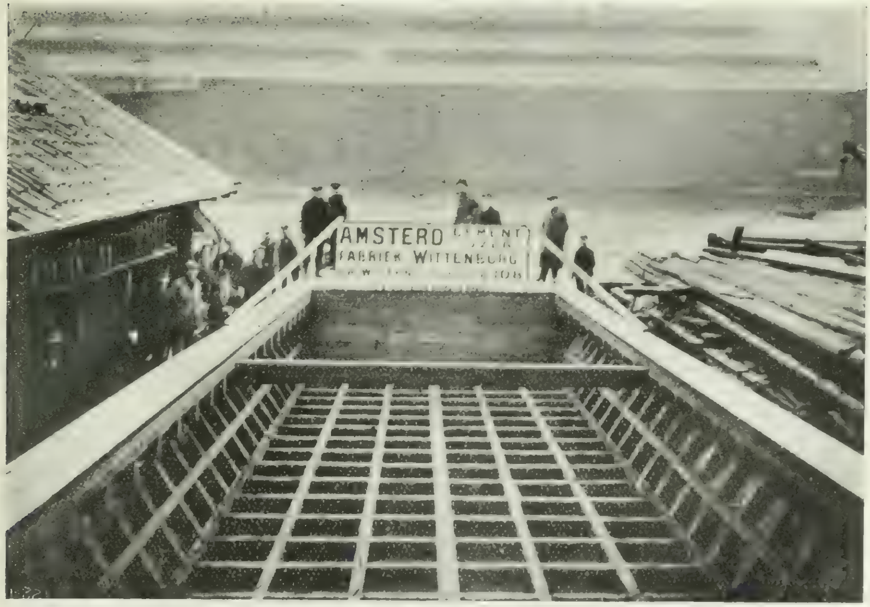


Fig. 14. Concrete Boat at Amsterdam during construction.

In 1917 concrete vessels were being built in all the chief maritime countries, and from this date the industry has developed so rapidly that it is convenient to adopt a geographical rather than a historical arrangement.

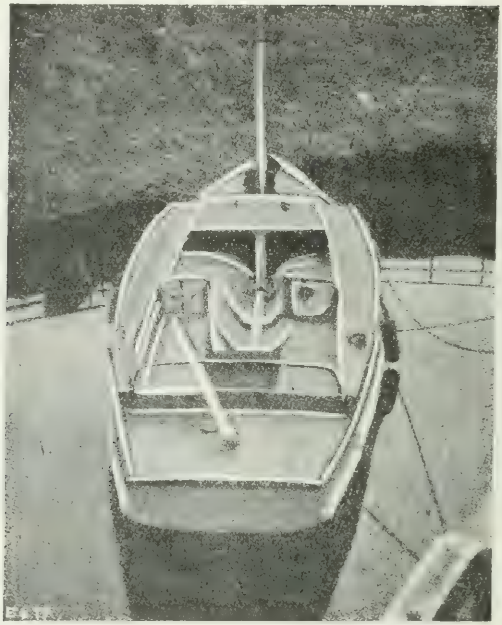


Fig. 15. An Italian Reinforced Concrete Barge.

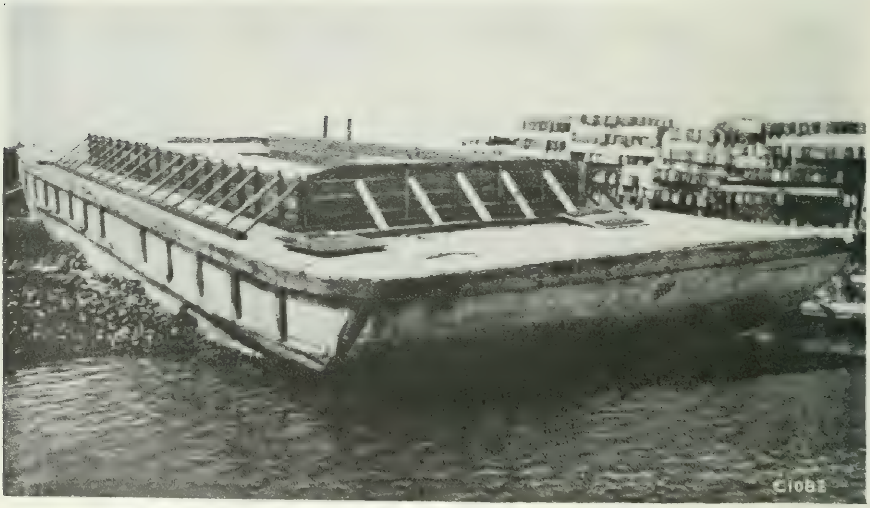


Fig. 16. Concrete Barge of the Gabellini Type, built at Mobile, Ala.

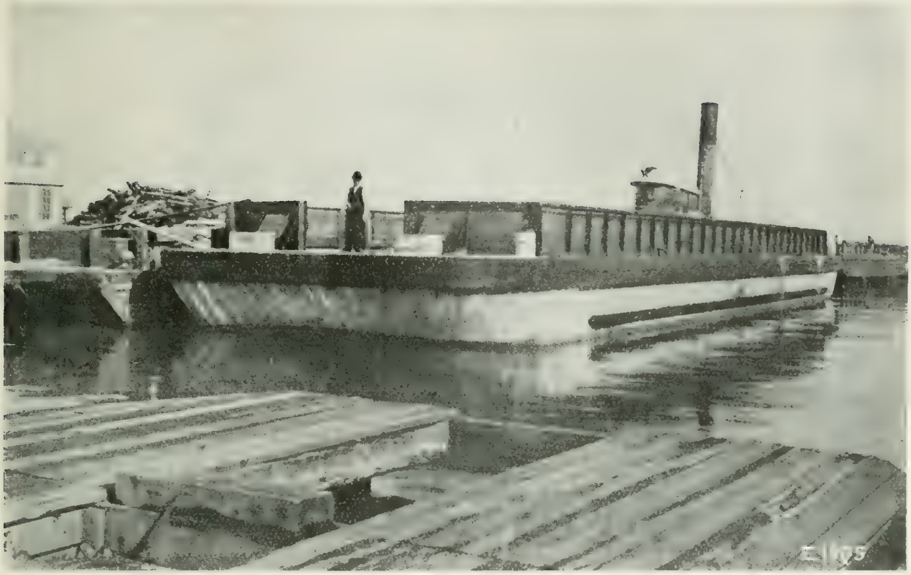


Fig. 17. Concrete Barge for Sand and Gravel at Baltimore.

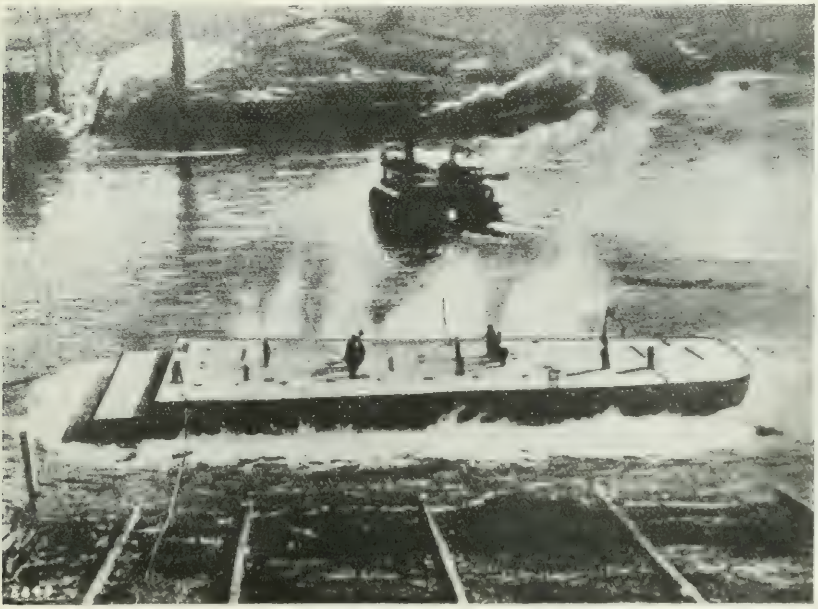
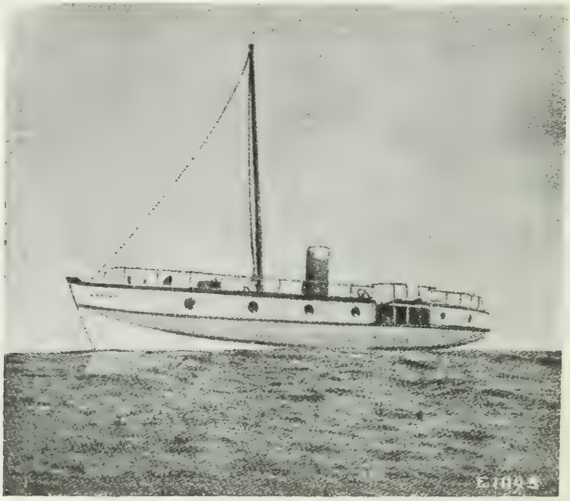


Fig. 18. Concrete Pontoons, Sydney, New South Wales.

In *Norway and Sweden* great progress has recently been made in the construction of concrete ships, particularly by two firms. N. K. Fougner, of Moss, has, since 1912, built several concrete vessels of 200 to 3,000 tons capacity, the first of these to make a sea voyage being the one shown in *Fig.* 21, which went from Moss to Christianiafjord in 1916. One of the Fougner Steel Concrete Shipbuilding Co.'s 400-ton single-screw boats—the *Namsenfjord* (*Fig.* 22), driven by a Diesel engine of 80 h.p.—was duly



By Courtesy of the "Motor Boat."]
Fig. 19. The 41-ft. Concrete Cruiser *Wanderer.*

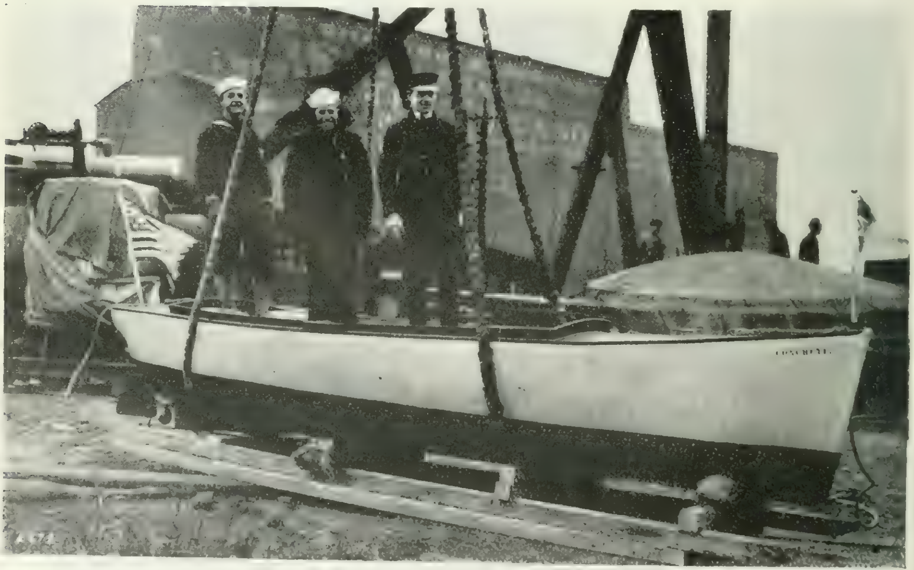


Fig. 20. View of the Concrete Boat taken over by the U.S. Naval Reserve.

registered at Lloyd's in 1917. She has an average speed when fully loaded of 7½ miles per hour, and has several times made the journey between Norway and the British Isles, her first journey to this country being made in December, 1917. A recent report from this firm states that they have on the blocks and well advanced one vessel of 4,000 tons, and three others of 1,600 tons each and one of 1,000 tons are begun. The firm is also building a lightship for the Norwegian Government, a large tug boat, and a number of floating docks, all of reinforced concrete.

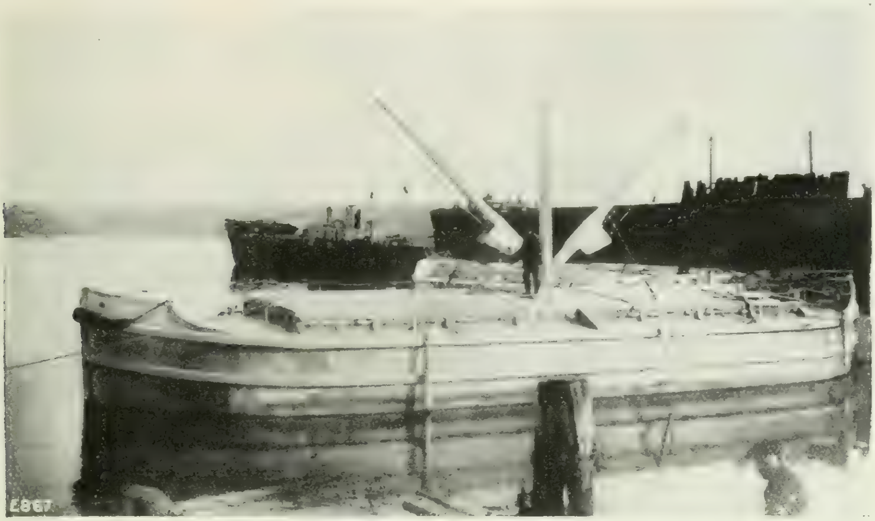


Fig. 21. Fougner Lighter of 100 tons D.W. Capacity used by the Norwegian Army.

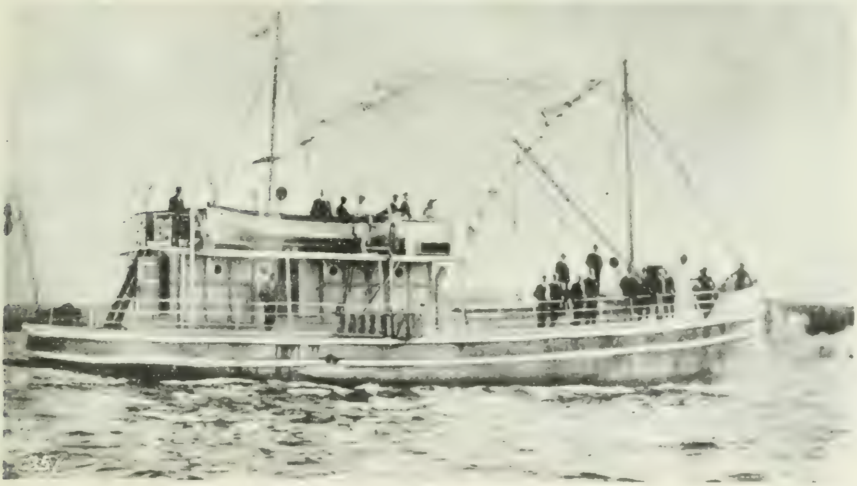


Fig. 22. The *Namsenfjord*.

Another Norwegian firm of concrete shipbuilders is the Porsgrund Cementstöperi A S, of Porsgrund, who attracted a considerable amount of attention by the ingenious manner in which they launched their vessels in an inverted position and allowed them to right themselves in the water. The first vessel built by this firm was the *Breton I*—a 200-ton motor boat—which was launched in this manner in August, 1917; the mode of launching is described in detail later on.

A. A. Boon, of Amsterdam (p. 5), has also built a 200-ton concrete vessel, 85 ft. by 21 ft. by 8 ft., at Malmo (*Figs. 23 and 24*).

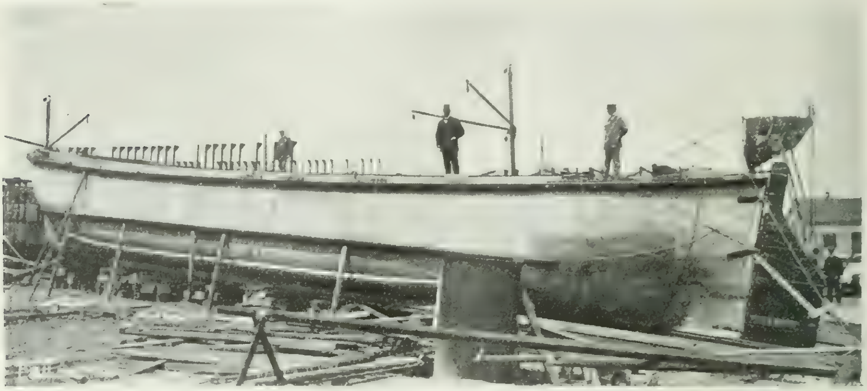


Fig. 23. A Barge in course of construction at Malmo.

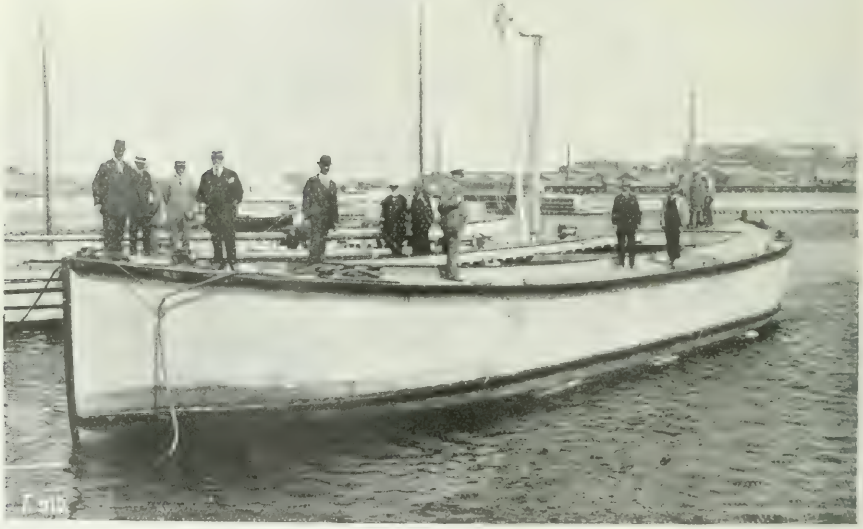


Fig. 24. The same Barge when launched.

(*To be continued.*)

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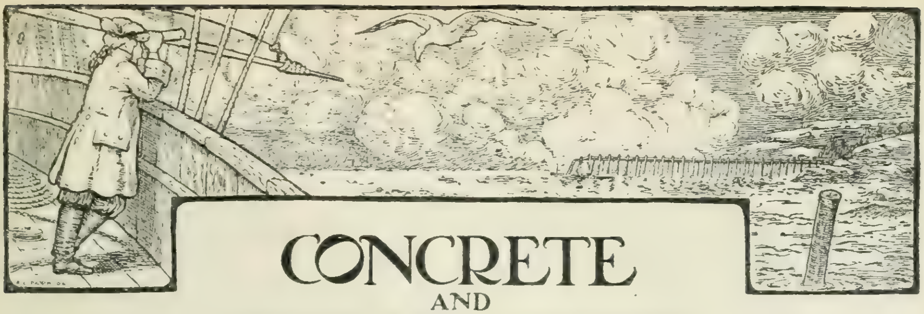

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

"CONCRETE SHIPBUILDING"

A Monthly Supplement

Issued Free to Subscribers DECEMBER, 1918 *Single Copies 1/-*

REINFORCED CONCRETE SHIPS, BARGES, AND PONTOONS.

By ALFRED B. SEARLE.

The present supplement is the second of a series of supplements we propose to publish giving a general review on the subject of concrete shipbuilding. In addition we hope in each number to include illustrations and particulars regarding current activities in this particular, as far as we are able to obtain and publish such information. It is hoped that these supplements will prove of use and interest to all those who are engaged in one branch or another of this particular form of the shipbuilding industry.—ED.

CHAPTER II (*concluded*).

A SHORT HISTORY OF CONCRETE SHIPBUILDING.

IN *France*—the original home of concrete vessels—little shipbuilding was done in this material for many years, but the industry has now taken a new lease of life and concrete vessels are being constructed in considerable numbers. Among the more important is a concrete barge 150 ft. by 26 ft., with a dead-weight capacity of 700 tons, remarkable for containing only 12 tons of steel, as compared with 85 tons in a boat of the same capacity built of steel in the ordinary manner.

The same builder, M. Lorton, has since constructed vessels with a displacement exceeding 5,000 tons.

The Association Commerciale de Constructions Maritimes has recently finished a 1,000-ton motor boat on the Hennebique system. The building of concrete ships on the Paris canal and on the Seine has proceeded rapidly during the last two years. Illustrations of some of these vessels are shown in *Figs.* 25, 26, 27, 28, *and* 29.

The construction of a considerable number of towing boats is now proceeding on the Seine, and the Société Pelnard-Considère, Caquot et Cie., has already built fifty of these vessels, each of 300 h.p., to the order of the Minister of Public Works. These boats are built in accordance with the regulations of the Bureau Veritas (the French equivalent of Lloyd's registry) so as to be amply strong enough for river transport with occasional short sea voyages. They are 83 ft. long with 17 ft. beam and 7 ft deep, with a total weight (for the hull alone) of 68 to 75 tons, and a displacement of 125 tons; they are designed to present a low resistance to progress through the water.

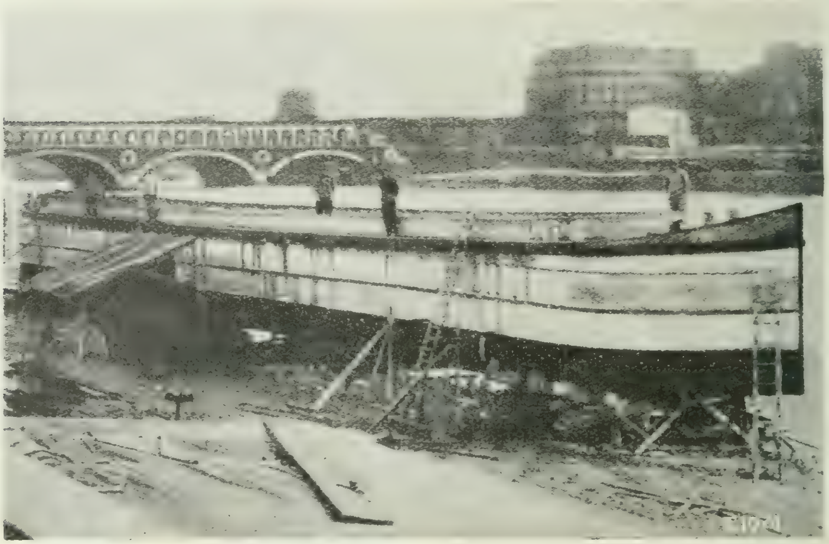

Fig. 25. Barge at the Quai d'Ivry, Paris, ready for launching.

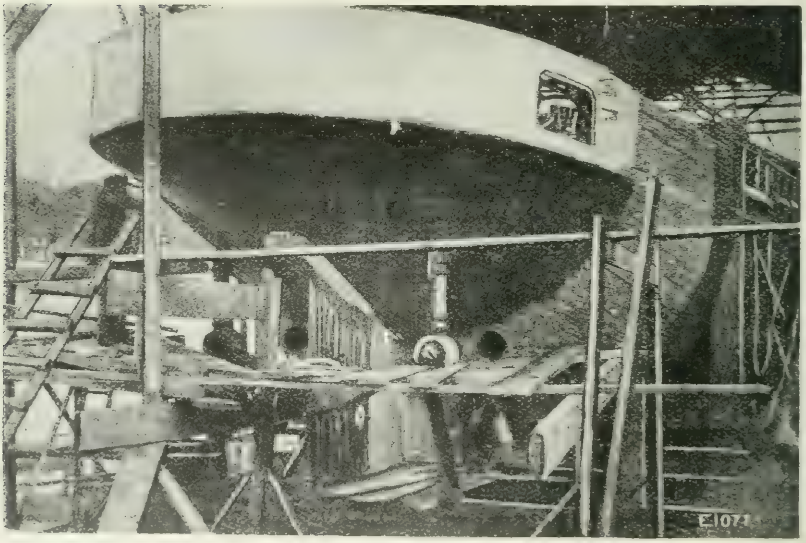

Fig. 26. Steam Tug at the Quai d'Ivry, Paris.

A large number of concrete barges and towing boats are now in regular use on the inland waterways of France.

La Société Entreprise Générale d'Etudes commenced the construction of a 450-ton concrete cargo boat on the C. A. Roux system early in 1918. This vessel,

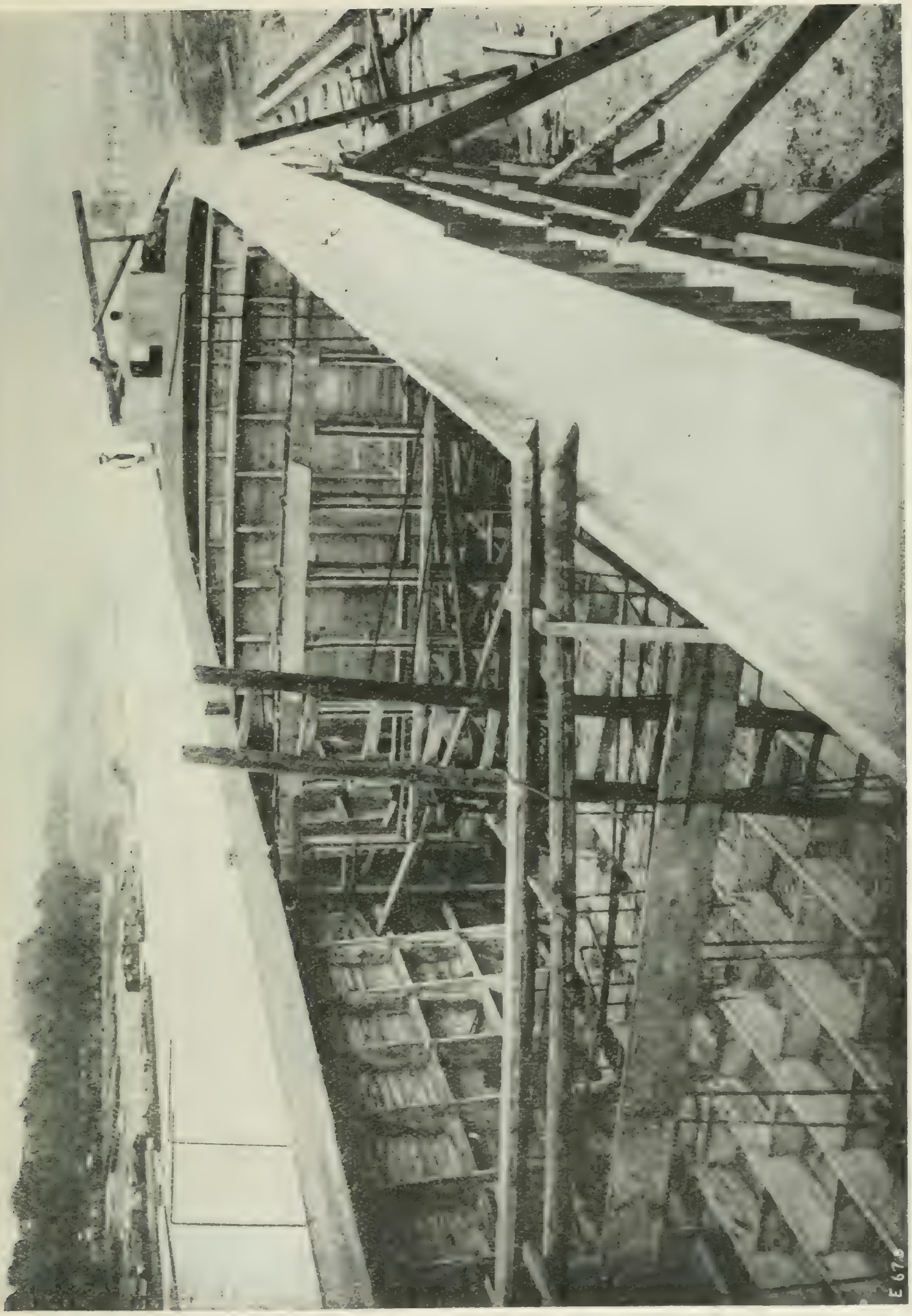

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Fig. 27. Interior of a Concrete Ship on the Paris Canal.

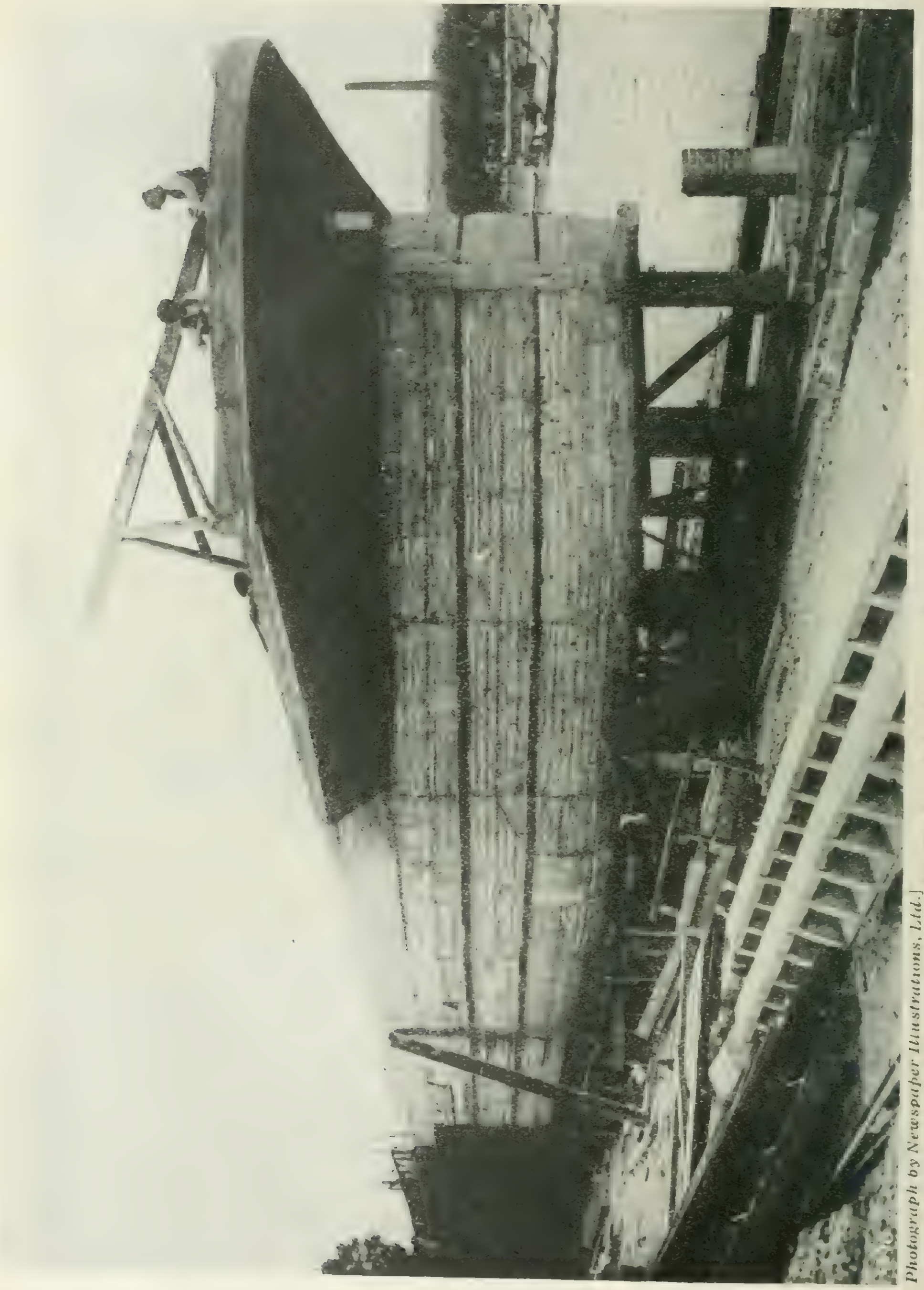

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Fig. 28. **Stern End of a Concrete Ship on the Paris Canal.**

which is intended for Cardiff-Paris traffic, has a length of 152 ft., total breadth of 26 ft., depth of hold 12 ft. 6 in., and draught of 10 ft. She will be driven by two petrol engines, each of 164 h.p., at an estimated speed of nine knots. Ten similar boats were due for completion before the end of 1918. The same firm has also commenced a series of similar boats for the Gironde and Mediterranean ; one of 1,000 tons capacity was begun in March, 1918, in the Gulf of St. Tropez. The firm propose to increase the capacity of each new boat by 500 tons, so as to gain experience without undue risk.

The Association Commerciale de Constructions Maritimes commenced a 1,000-ton motor boat early in 1918, to be reinforced on the Hennebique system.

In the *United States*, the following concrete ships are in actual use. By the time these lines appear in print a considerable number of other concrete vessels will have been launched as the construction of such ships is proceeding very rapidly in the States. :—

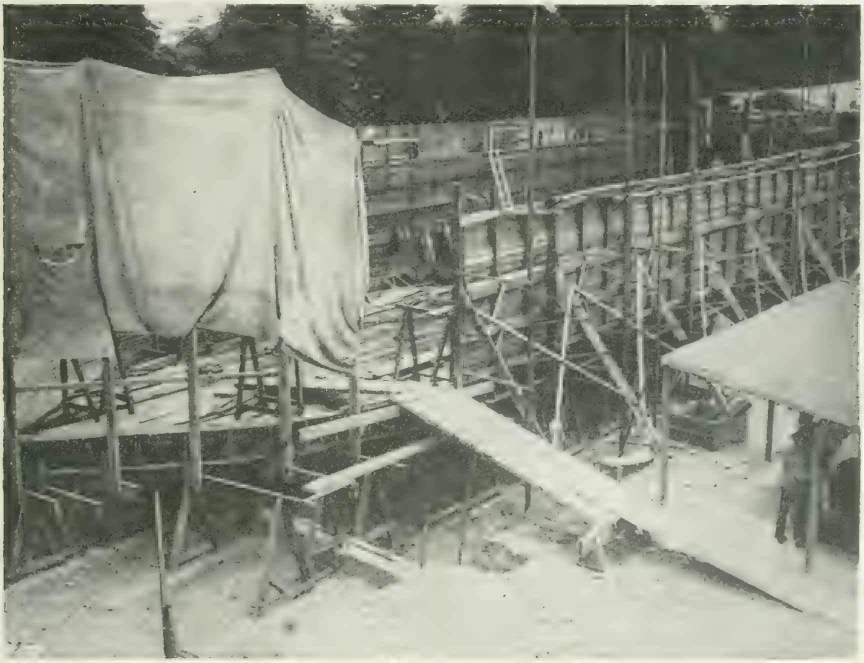

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Fig. 29. The Cage in which the Concrete Ship was built on the Paris Canal

A reinforced concrete scow was built at Michigan City, Ind., in 1913, for use on the lake, which has a carrying capacity of 25 tons and is 40 ft. by 14 ft. by 3 ft. 6 in., with a 3 in. shell.

The Lord Construction Co., of New York, has just completed two reinforced concrete barges of 300-tons capacity of two types : one specially for deck loading and the other for dealing with coal and grain. Both these types are specially designed for use in the Great Lakes and on the Erie Canal.

The Louis L. Brown Co., of New York, has built a 700-ton barge, 112 ft. by 33 ft. by 10 ft.

Early in 1917 a large yard was established at Redwood City on the Oakland Estuary, San Francisco Bay, for constructing concrete barges for the traffic between

San Francisco and Sacramento. These barges are to be of 526 tons dead-weight capacity. The San Francisco Shipping Co. has, however, gone far beyond its original moderate intentions, and has constructed by far the largest reinforced concrete vessel which has yet been built. This vessel—the *Faith* (*Figs.* 30 to 34)—was launched on March 14th, and made her trial trip on May 5th, 1918. Since then this vessel has made a return voyage to Vancouver in rough weather in a completely satisfactory manner. This vessel has a capacity of 5,000 tons, and is 320 ft. by 44 ft. and 30 ft. deep to the upper deck, with a draught of 24 ft. She is fitted with triple-expansion engines of 1,750 h.p. The trial cruise lasted for four hours, and covered a distance of nearly forty miles. Many elaborate tests were conducted with satisfactory results. The instruments used for the purpose showed that the vibration was negligible, the vessel in turning made 2½° on the heel, which is quite satisfactory, and the measured miles was traversed at a speed of 10¼ knots.

The following report by one of the surveyors to *Lloyd's Register* is important on account of the admitted impartiality of the writer :

> Concrete steamer *Faith*—Dims., 320 ft. by 445 ft. by 30 ft. mld. This vessel left San Francisco May 22nd, 1918, with a cargo of salt and copper ore, bound for Seattle, Tacoma and Vancouver. Draft forward, 21 ft. 10 in. ; aft, 23 ft. After rounding Point Reyes in the afternoon encountered strong head winds with considerable sea, to which the ship responded very well, although a good deal of water was shipped on deck. On Thursday afternoon, the wind having increased in violence and the ship shipping seas all fore and aft and making about two knots per hour, the captain wore ship, running back to shelter cove until the storm abated.
>
> Left shelter cove at 4 a.m. on Friday, and shortly afterwards ran into a gale ; the ship was pitching heavily, but pounded rather hard, due probably to shape of forward under body. This continued all day and during the night, when the gale was at its height, and which the captain estimated to have a velocity of 60 miles per hour. During the day the vessel was taking seas over forecastle and all fore and aft, but responded well to these head seas, much in the manner of a steel vessel.
>
> On Saturday the wind had fallen considerably and on the afternoon of that day the gale had subsided, which gave the opportunity of removing a hatch cover from Nos. 1, 2 and 3 holds and examining the vessel as far as the cargo permitted. It was then observed that the deck slab was cracked in several places in way of Nos. 1, 2 and 3 hatchways under the winch seatings, those cracks being more extensive in way of No. 2 hatchway. The cracks extended right through the slab, and evidence of slight leakage could be seen on underside, and were confined in extent to the area between the hatchways and under the winches. Small hair-line cracks were also observed in the inside surface of the radius corners of all the hatchways, more particularly in No. 2. A certain amount of leakage also occurred through the fastening of the wooden deck houses and other deck fittings through the slab, and also from the fender bolts along the ship's side.
>
> From Saturday afternoon until the arrival of vessel at Seattle on Tuesday, May 28th, good weather prevailed. Draft on arrival : Fore, 21 ft. 3 in. ; aft, 22 ft. 8 in. During the voyage the bilges were sounded every hour, day and night, and except for port side No. 1 hold, which had about 5 in. on arrival, all other bilges were dry ; this leakage only amounted to about a barrel full, and in my opinion was due entirely to seepage from cargo. After unloading part cargo, left Seattle on Thursday, May 30th, arriving Tacoma same day. Left Tacoma Saturday, June 1st, arriving the following day at Vancouver, where remainder of cargo was discharged. On Friday afternoon, June 7th, the vessel being then empty, was subjected to a thorough examination as far as possible outside and inside. The outside inspection showed cracks on the paint running parallel to the outer layer of reinforcing rods, particularly over the midship portion of vessel and on the port bow, and were probably caused by a slight movement of the slab with the force of the seas. On the inside of vessel, in addition to the cracks in deck slab previously mentioned, hair cracks were observed in the walls between upper and second deck extending from about the middle of hold No. 1 to middle of hold No. 3. These are probably shrinkage cracks and had been under observation before ship left San Francisco. In the lower holds at about the centre of No. 2 and 3 hatchways, on both sides, hair-line cracks were observed in the shell slab and extending across one longitudinal. These cracks showed slight working and were the only ones seen below the second deck, and were probably caused by straining when labouring in a cross sea.

Apart from these minor failures, the ship, in my opinion, is a success ; the failure of the deck slab is due to lack of sufficient reinforcement, and owing to the winches being bolted through the cement slab without any seatings.

The deck arrangements are only suitable, in my opinion, for coastwise trade, a wooden deck house bolted through the deck slab being the only protection for the engine and boiler openings, which, in my opinion, is not enough for transoceanic service. A concrete poop enclosing these openings would be a decided improvement. At the various ports of call the vessel was visited by large numbers of people representing the various shipping and shipbuilding interests, and their criticism on the whole was favourable to this type of construction.

Professor McMillan had a number of strainograph instruments placed around the midships of vessel, the cargo being so arranged that these were accessible at all times during the voyage, access to them being obtained through a ventilator to No. 2 hold. He found that the greatest stress registered during Friday's gale was only 8,000 lb. (that is, between hogging and sagging), on the indicators placed on the underside of deck, and the indicators on flat of bottom registered about threequarters of that amount.

The following is a copy of some of the observations made by Mr. C. C. Brush, assistant engineer, Bureau of Lighthouses :

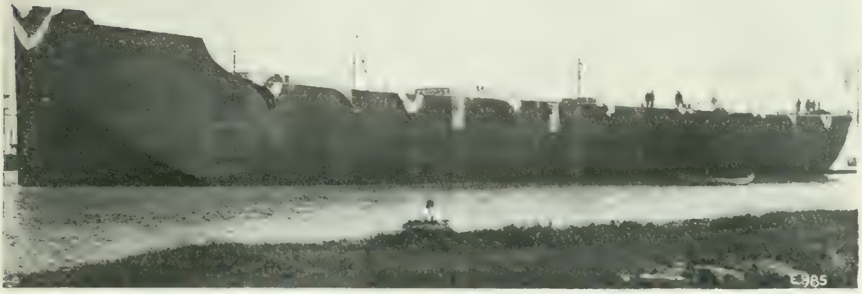

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Fig. 30. The Concrete Ship *Faith* after launching.

"Established sight lines fore and aft, reading 0 in still water ; passing out through Golden Gate vessel showed slight hog of ¼ in. port and ⅜ in. starboard, and the greatest deflection taken during the voyage between extreme hogging and sagging was ⅞ in. in a length of 180 ft. which is about one-third of what a steel ship would show under similar conditions."

Bearing in mind that this vessel was the first of its size to be built of concrete, that its construction was unduly hurried, and that the defects are all minor ones, this report must be regarded as extremely satisfactory.

A good idea of the size of this vessel may be gained from *Fig.* 30, which shows the hull when nearing completion, and *Fig.* 33, which shows the prow. It is noteworthy that although the *Faith* was built in the United States, its initiation was due to a British shipowning company, so that this country may justly claim a share in the construction of this epoch-making vessel.

Since the first commitment of the American Shipping Administration to the policy of building concrete tonnage, plans have been pushed rapidly for the development of this type of ship.

The construction of a total of forty-two new concrete ships has been authorised by the United States Shipping Board, and contracts for eighteen have already been placed. These concrete ships will be tankers of 7,500 tons each, with a capacity of 50,000 barrels of oil, engines of 2,800 h.p., and a speed of 10½ knots an hour, together with a few cargo ships of 3,000 and 3,500 tons. The forty-two concrete ships will have a total of 298,500 dead-weight tonnage.

The concrete ship department of the United States Shipping Board, Emergency Fleet Corporation, of which R. J. Wig is chief engineer, has also prepared a design for a 3,500-ton ship, of which two are to be built.

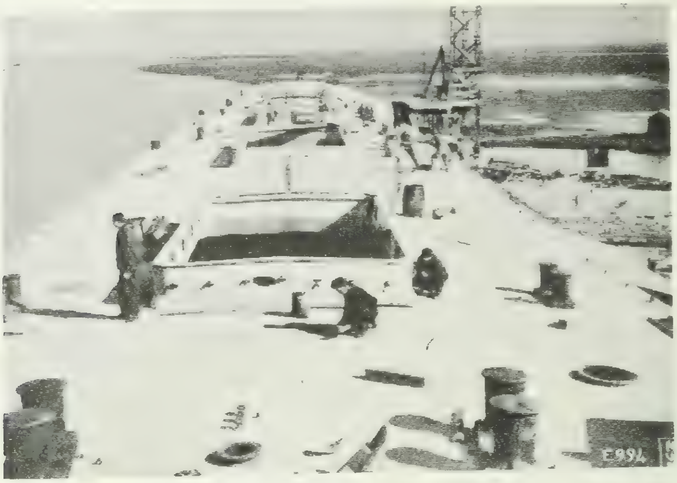

Fig. 31. Deck View of the *Faith*.

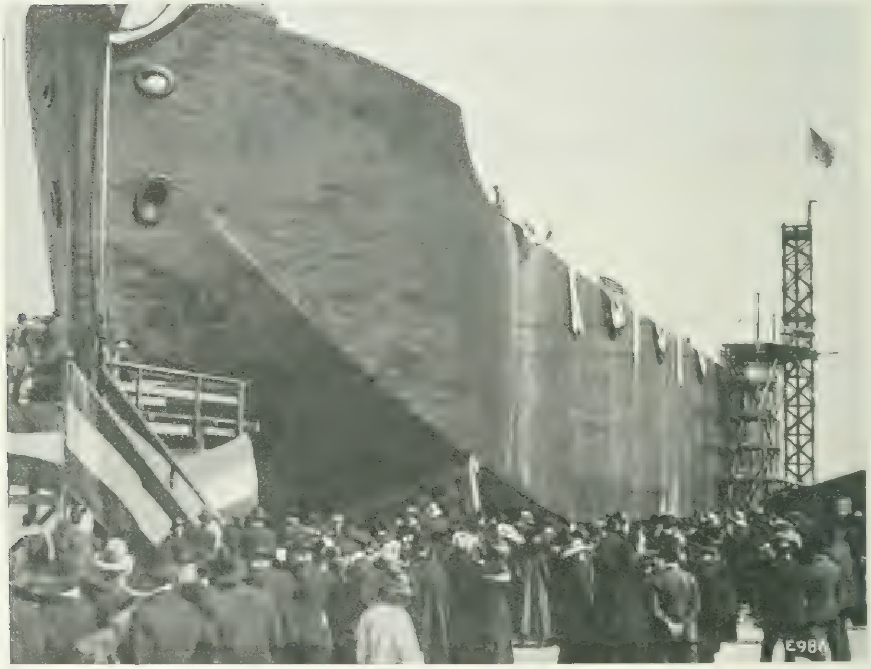

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Fig. 32. The *Faith* prior to launching.

To utilise the already designed and partly manufactured engines and fittings for the Fleet Corporation's standard wooden ships, the first standard concrete ship was made of approximately the same capacity, dimensions, and form, except that the sheer line amidships of the concrete ship has been slightly altered, and no exterior keel is fitted. The general arrangement of the ship itself and of the propelling machinery is the same in both types. The vessel is of single deck over its full section, with a poop deck at the stern, a forecastle deck at the bow, and a bridge deck, with a wooden-frame cabin-house amidships.

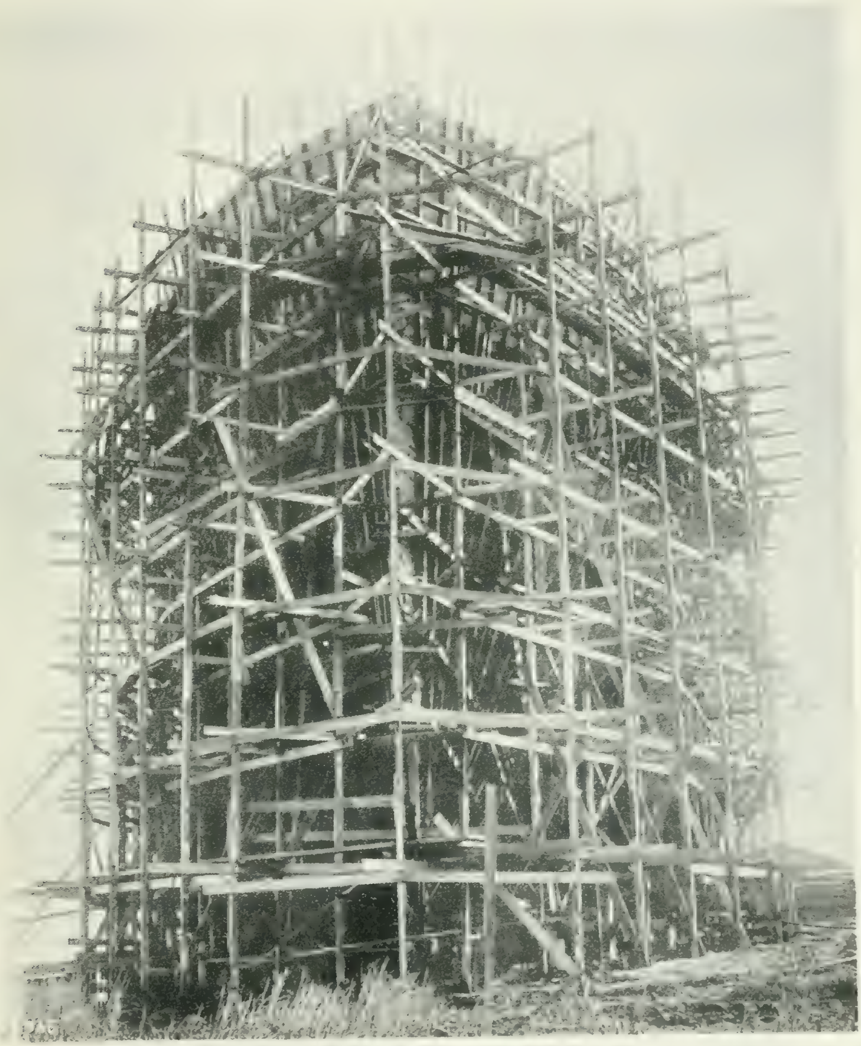


Fig. 33. The Prow of the *Faith*.

She has a length overall of 281 ft. 10 in., a length between perpendiculars of 268 ft., beam over shell of 46 ft., depth amidships at sides of 28 ft. 3 in., a loaded draught of 23½ ft., and a carrying capacity of 3,203 tons. She compares closely in these dimensions with the similar wooden ship of somewhat larger dead-weight carrying capacity, but it is nearly twice as heavy empty as a steel ship. A single screw, turned by a 1,400-h.p. reciprocating engine, located amidships, will give a speed of approximately 10½ knots.

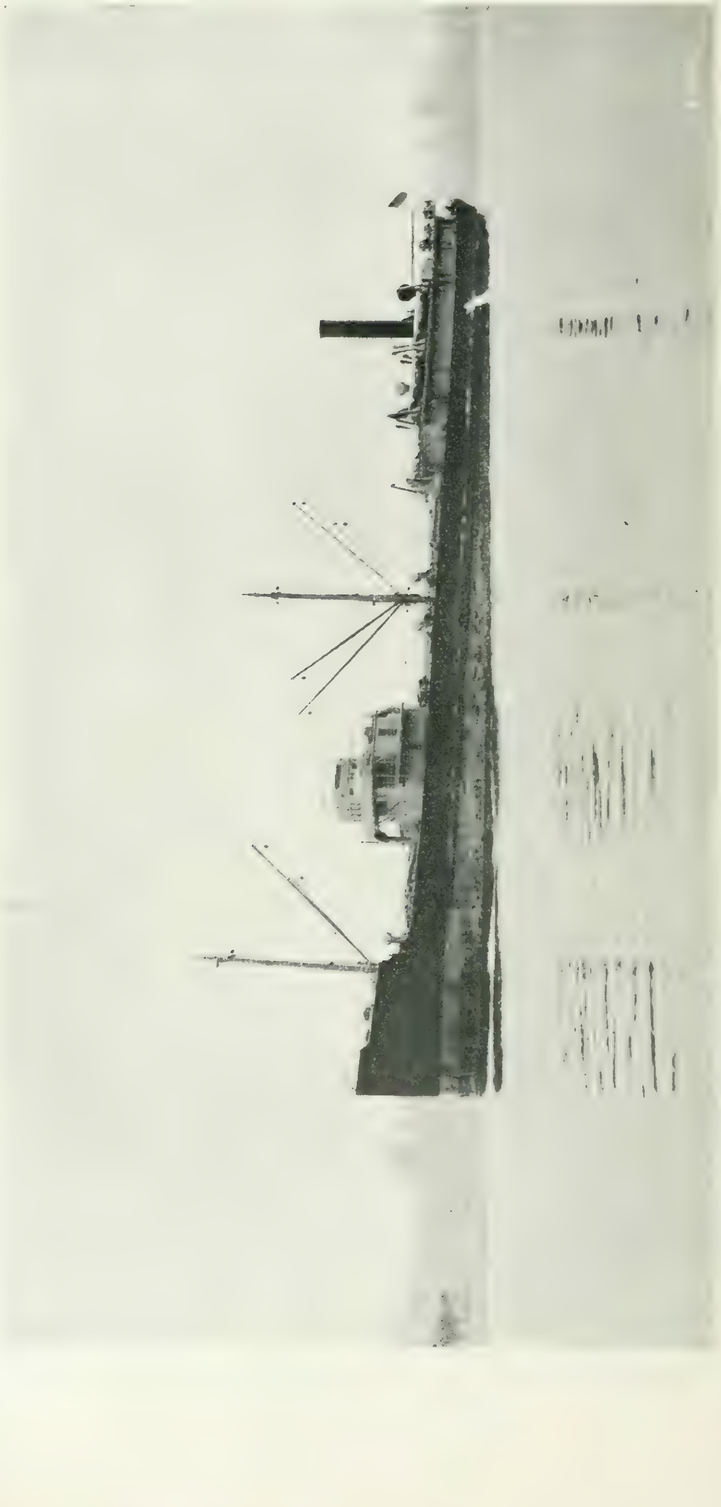


Fig. 34. View of the Reinforced Concrete Ship *Faith* leaving Vancouver Harbour.

In *Great Britain* it is commonly supposed that concrete vessels are only used to a very limited extent, but careful enquiry will show that there are many more than is generally known. Yet, in spite of an apparent backwardness at first—due partly to national conservatism and partly to an abundance of steel and skilled labour until quite recently—there is now a considerable number of firms engaged in this branch of the shipbuilding industry ; orders for several hundred reinforced concrete barges are in hand and several larger vessels are in an advanced stage of construction.

One of the oldest concrete vessels in this country is a pontoon 100 ft. by 28 ft. by 8 ft. 6 in. (*Fig.* 35), built in 1912 by the Yorkshire Hennebique Construction Co., Ltd., of Leeds, to the design of L. G. Mouchel & Partners, Ltd., for carrying sludge, pumps, fuel, etc., on the Manchester Canal. Its bottom and walls are 3 in. thick and it has proved to be remarkably durable, costing less than was anticipated in maintenance, and such small repairs as are necessary can be made without putting it out of service.

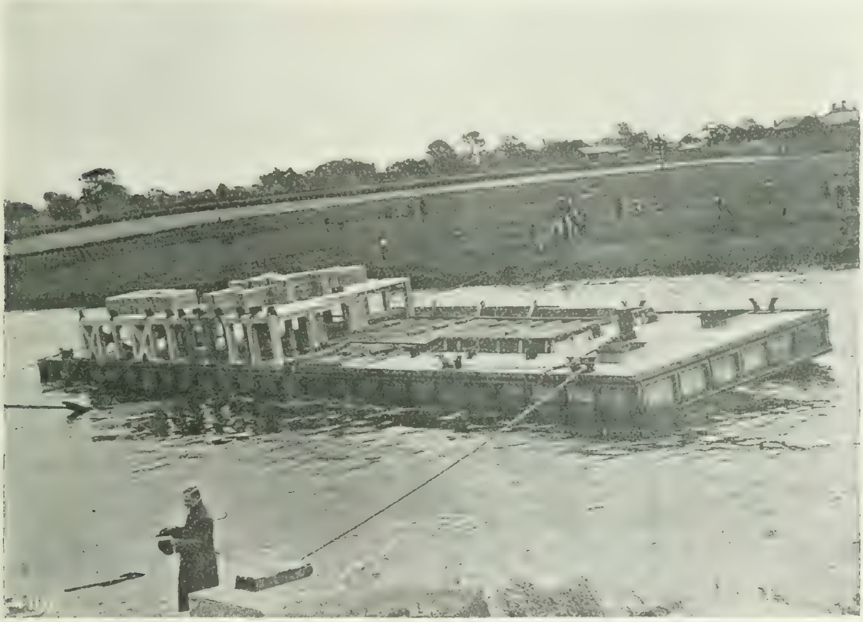


Fig. 35. Concrete Pontoon at Irlam on the Manchester Ship Canal.

What was announced as " the first large sea-going concrete vessel built in the United Kingdom " (*Fig.* 36) was completed in April, 1918, under the supervision of J. & W. Stewart, of London. She is a towing barge 150 ft. long by 25 ft. broad, with a draught of 11 ft., a displacement of 900 tons, and a dead-weight capacity of 400 tons. Strength rather than lightness and economy was a feature of her construction, and in order that close comparisons might be made between her and existing steel vessels, she was constructed as nearly as possible on the lines of the latter, notwithstanding the additional expense in moulds which was involved. This vessel has been classified as A1 by Lloyd's.

What is stated to have been the first motor *cargo* boat to have been launched in England (*Fig.* 37) was built by Holland, Hannen & Cubitts, Ltd., at Chiswick, early in 1918. She is 40 ft. long, 8 ft. 6 in. wide, and 4 ft. draught when loaded, and is fitted with a 25-h.p. motor designed to drive her at a speed of eight miles per hour.

The first reinforced concrete barge to be used entirely for commercial purposes constructed in this country is one known as a " monkey " barge, she having no cabin accommodation. Barges of this type are employed in canal traffic in the Midlands, and are confined to certain overall dimensions owing to the locks through which they have to pass. The one shown in *Fig.* 38 was designed by Mr. E. P. Wells, of

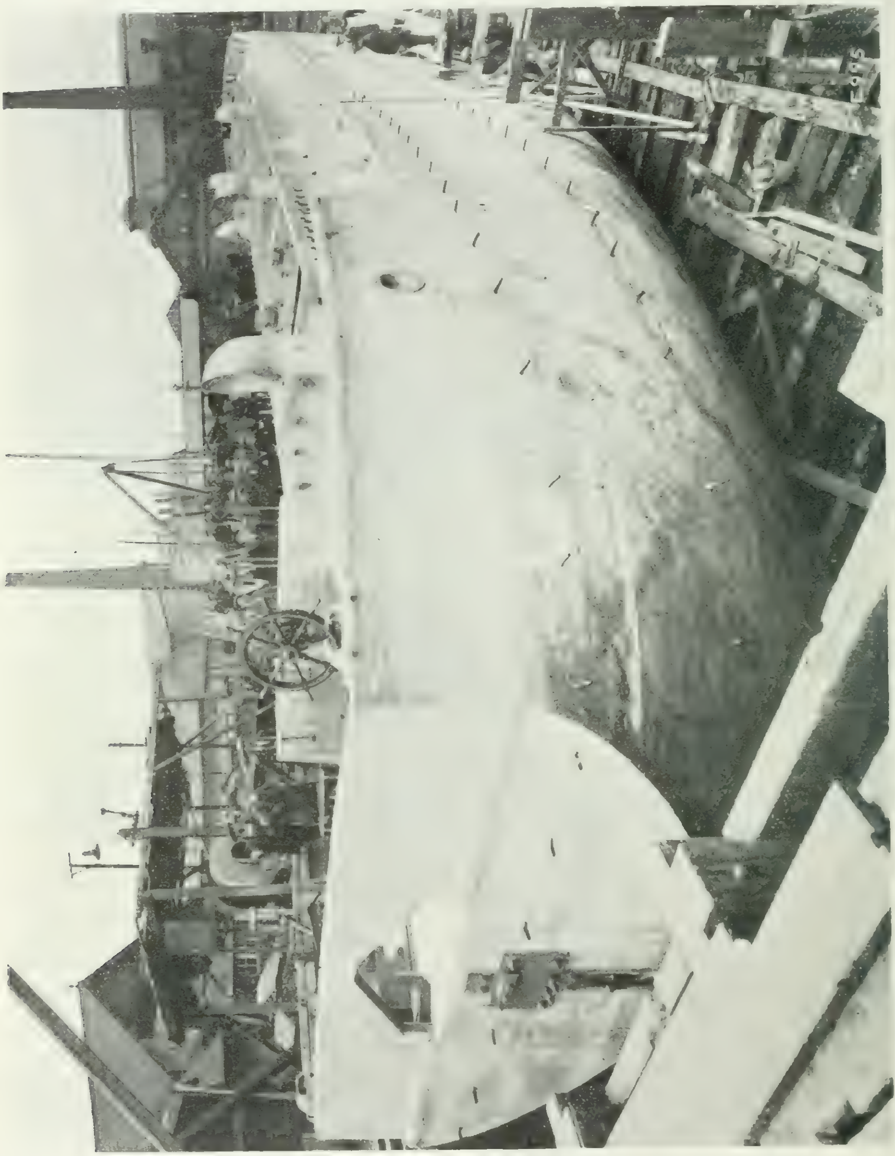


Fig. 36. Great Britain's First Concrete Sea-going Vessel. The two rows of bolts projecting from the concrete are for attaching the wooden fenders which protect the concrete.

Clapham, and was constructed by Mr. A. H. Guest, of Stourbridge. She is 70 ft. in length over all by 6 ft. 11 in. in width over the fenders by a total moulded depth of 4 ft. When unloaded she has a draught of 14 in. as compared with $7\frac{1}{2}$ in. to 9 in for wooden or steel boats of similar tonnage, but to compensate for this an extra moulded depth of 6 in. has been added so that the barge will carry the same dead load, and be registered like one of wood or steel. The approximate dead load that she will carry is about twenty-seven tons, though, of course, in measurement she will carry a very much greater cargo. In order to conform to the preconceived ideas of the canal " bargee," the usual design with frames was adopted, though in future barges it is proposed to simplify the construction. The barge took about one month to construct owing to the fact that she was the first of her kind, and also owing to the very bad weather that was experienced during the latter end of the summer and early autumn. The actual time occupied in moulding was about six days, and the boat was launched within eight days after completion of the topsides. She was then kept for a further ten days before she took her first cargo of sand. The times between finishing and launching and between launching and loading are merely stated as facts. That they are unusually short will be recognised by everyone who is experienced in concrete construction. That they were possible is due to special circumstances. As a general rule it would be safer to allow a much greater length of time in each case. No plastering or finishing coat was applied to this barge.

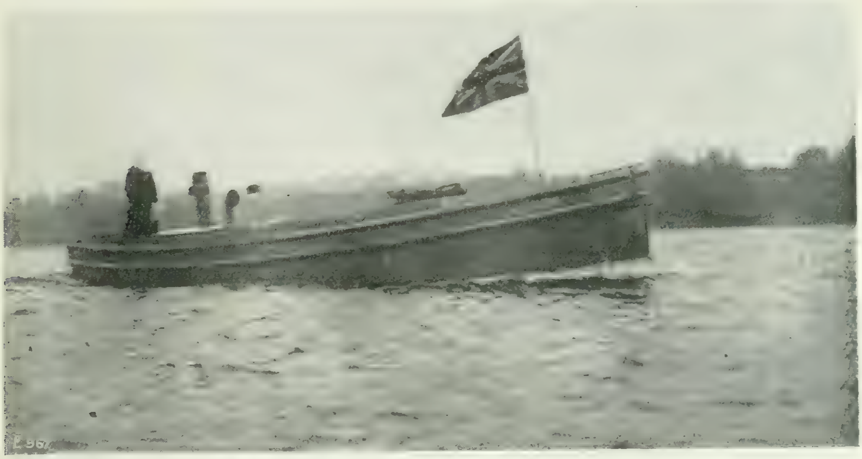


Fig. 37. **A 20-ton Concrete Cargo Boat built on the Thames.**

Another barge has also been built to the same design, only with about 4 in. sheet at both the fore and after ends in order slightly to improve her appearance and render her lines more acceptable.

Among other firms who have published information as to their work are James Pollock & Sons, Ltd., London, who are engaged in building several concrete motor coasting vessels, 92 ft. by 19 ft. by 10 ft. of 120 h.p. The same firm have also completed several other concrete barges, including one of 130 tons capacity for the Thames.

The Ferro-Concrete Construction Company, Barrow-in-Furness, have constructed a steamship of 1,150 tons dead-weight capacity driven by a 400 h.p. engine at $7\frac{3}{4}$ knots, and others of the same pattern are under construction.

One firm has recently commenced in the south of Ireland, and another in the north of Scotland.

In August, 1917, a concrete motor launch (*Cementus I.*), (*Fig.* 39), of the fast estuary type, designed by Mr. J. C. Snelling and built by Messrs. Muribloc, Ltd., was launched on the Thames, and thoroughly tested with good results. This vessel is 21 ft. by 5 ft. 3 in. by 14 in. draught, with a shell only $\frac{5}{8}$ in. thick. Her weight is about 30 cwt. and her speed about 9 knots. In September, 1917, this launch towed at three knots in slack water a barge of 160 tons, and considering the smallness of the motor—1 c. 7 h.p.—the result was very satisfactory, and testifies to her very smooth under-water surface. She was also tested by being supported at either end

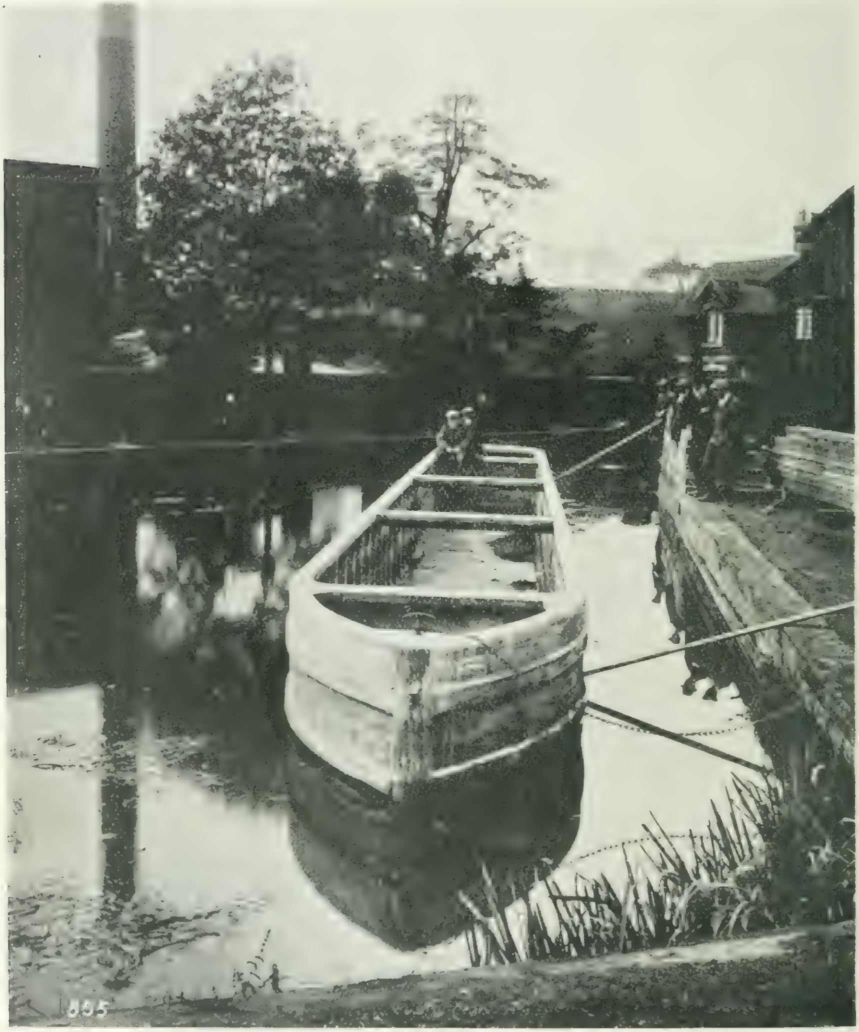


Fig. 38. First Concrete Barge built in England, and designed by A. N. Guest for use on Midland Canals.

and treated as a beam, and by being pivoted at the centre as a double cantilever, without showing any sign of strain in either case.

There are seven watertight compartments, the divisions, the seats and floors being only ⅜-in. thick; tested full of water, the compartments showed no sign of damp on the inner surface. There is no woodwork in any part of the boat, so that, besides being fire-resisting, she may be said to be rot-proof.

The vessel has proved to be remarkably strong and resilient. During her life on the tideway she has been subjected to some very heavy knocks, many of them sufficient to stove in the planks of a timber boat of her size. It is believed by the designers that she is the first fully-lined light reinforced concrete motor boat which has yet run in this country.

A neat rowing boat, built by Mr. J. Bowman, of Montrose, Scotland, in 1917, is shown in *Fig.* 40. She is 12 ft. by 4 ft. 2 in. by 2 ft. 9 in. deep, and can easily carry four persons.

The magnitude of the effort now being made in this country is shown by the establishment of a score of reinforced concrete shipyards in the West and South of England, in the Thames district, on the north-east and north-west coasts of England, on the Clyde, and at Aberdeen in Scotland, and in the East of Ireland. At these yards some 220 vessels are in course of construction, representing a total of about 200,000 tons of shipping. Only a few weeks after the decision of the Government to begin reinforced concrete shipbuilding, between seventy and eighty slipways were laid down by firms of public works contractors and newly-formed shipbuilding companies, and at the present time several vessels of 1,000 tons dead-weight capacity are on the point of completion, and will soon begin to follow each other into the water, to be succeeded in turn by others already on the slips.

The vessels at present in course of construction for the Controller-General of Merchant Shipbuilding comprise dumb barges of 1,000 tons dead-weight carrying capacity and steam tugs of 750 h.p. In addition, six cargo steamships of 1,150 tons dead-weight capacity are being built for private ownership, and designs have been prepared for steamships of much larger size, which will soon be constructed. All the barges and steam tugs, 187 ft. 6 in. and 125 ft. in length respectively, now under construction in controlled shipyards are being built in accordance with the specification and general drawings issued by the Admiralty Department of Merchant Shipbuilding. The details of the hull and of the reinforced concrete construction are, however, to be in accordance with working drawings prepared by or for the various shipbuilding firms, and, in consequence, a considerable amount of latitude is given for the employment of different systems of reinforcement and methods of construction.

Most of the vessels are being moulded on the monolithic principle, and embody systems of reinforcement which have been used extensively for land structures. In some cases, however, the pre-cast slab method of hull building has been adopted, and novel systems of reinforcement have been devised. In other instances the bottom of the whole of the hull is being built on the cellular principle, while in others, again, the hull consists of a single shell stiffened by transverse frames at frequent intervals.

The Barnstaple branch of the British Construction Company, of Westminster, has seven slipways whereon four 1,000-ton barges and two tugs are already nearing completion. The work of concreting the first barge was finished early in August, 1918, and the vessel was launched at the end of that month.

At the Gloucester Ferro-Concrete Shipbuilding Co., Ltd.'s establishment on the eastern bank of the Gloucester and Berkeley Ship Canal four barges were on the slips in August, 1918; one was being concreted, and arrangements were made to carry on the work day and night, Sundays included, with the object of securing perfectly monolithic work. The other three barges were at that time well on the way and ready for concreting in regular succession.

The Gloucester Ferro-Concrete Shipbuilding Co., Ltd., has installed pumps and a system of pipes by means of which the shuttering and moulds are kept moist until the concrete has thoroughly seasoned.

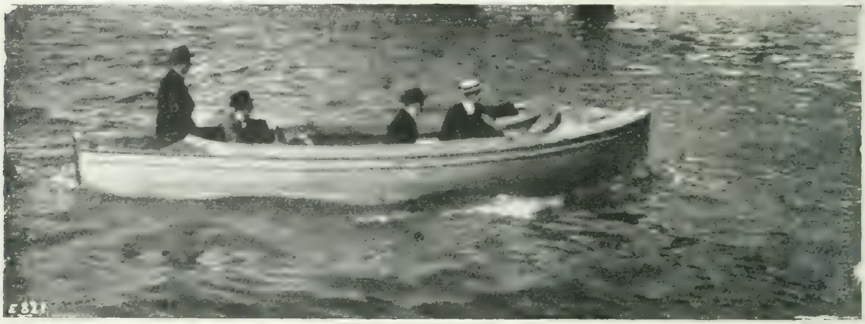


Fig. 39. The Concrete Motor-Boat *Cementus I.*

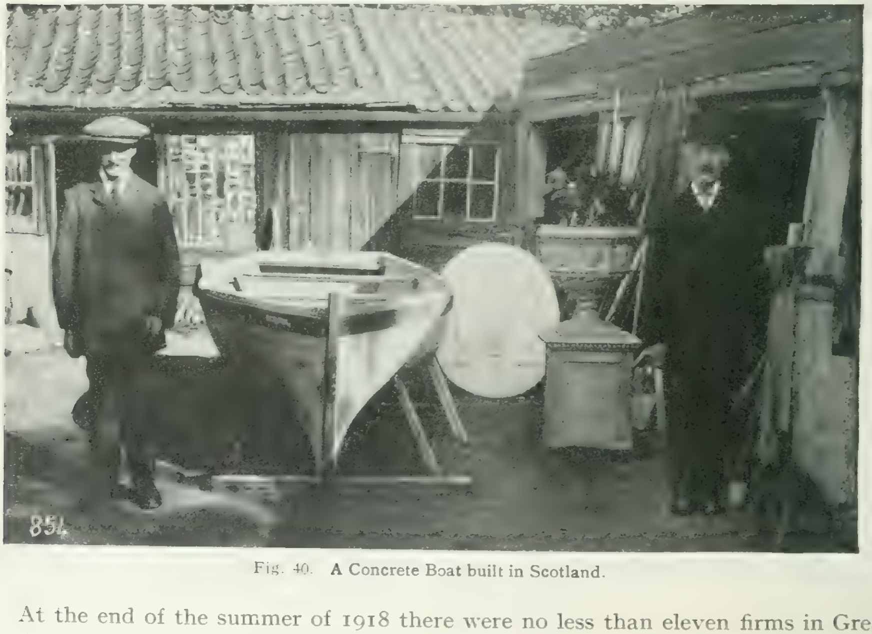


Fig. 40. A Concrete Boat built in Scotland.

At the end of the summer of 1918 there were no less than eleven firms in Great Britain engaged in the construction of concrete vessels of 100 tons capacity and upwards. Detailed descriptions of these works and the boats they are building will be given later, and their existence shows that we in this country are fully alive to the advantages of concrete as a shipbuilding material.

In other countries considerable progress has been made recently, the following being the most noteworthy advances:

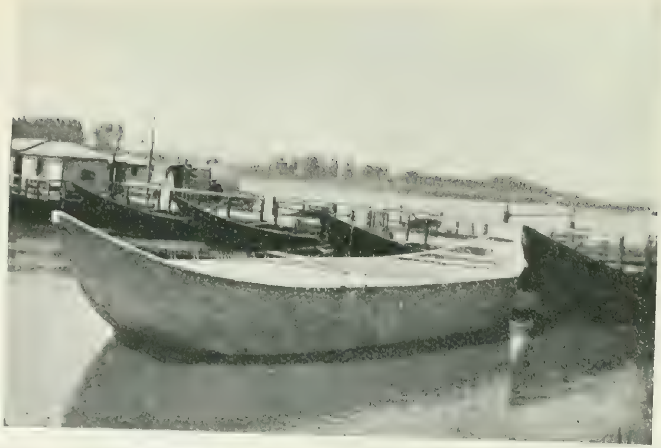


Fig. 41. Small Reinforced Concrete Pontoons on the River Po, for a Floating Bridge near Pavia.

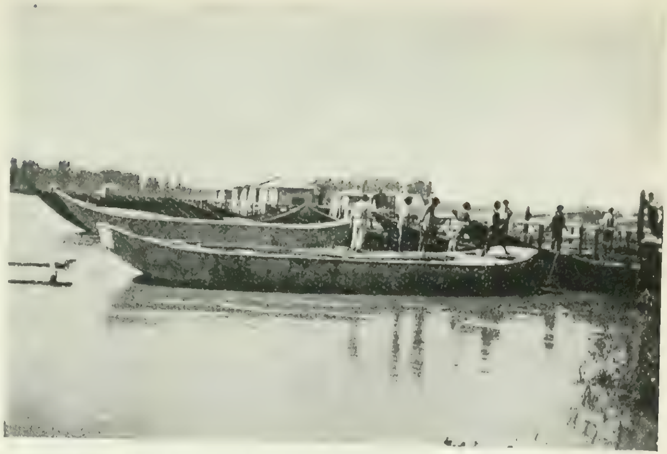


Fig. 42. Two of a series of 60 Reinforced Concrete Pontoons for a Floating Bridge. Length 42 ft., Beam 14 ft.

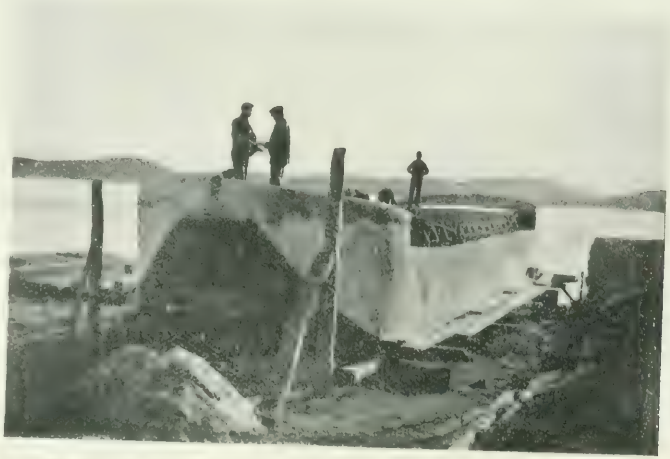


Fig. 43. Heavy Reinforced Concrete Pontoon in course of construction.

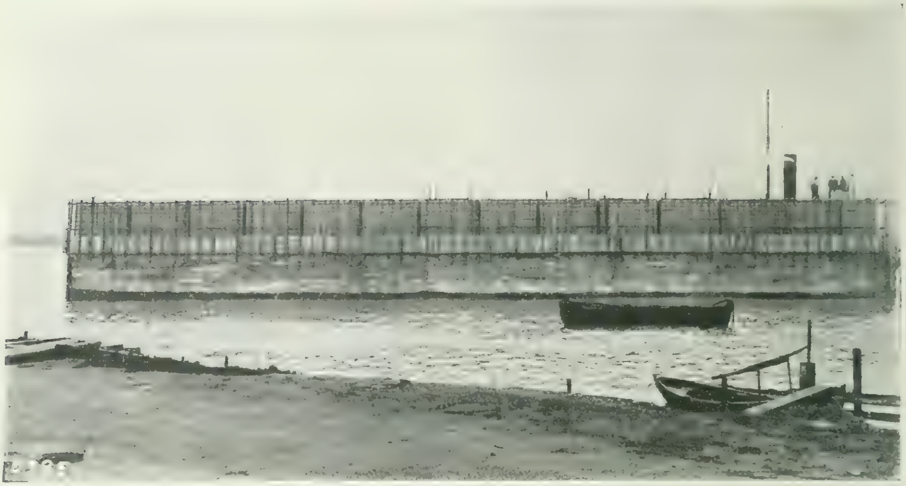


Fig. 44. Reinforced Concrete Caisson at Copenhagen, being towed into position.

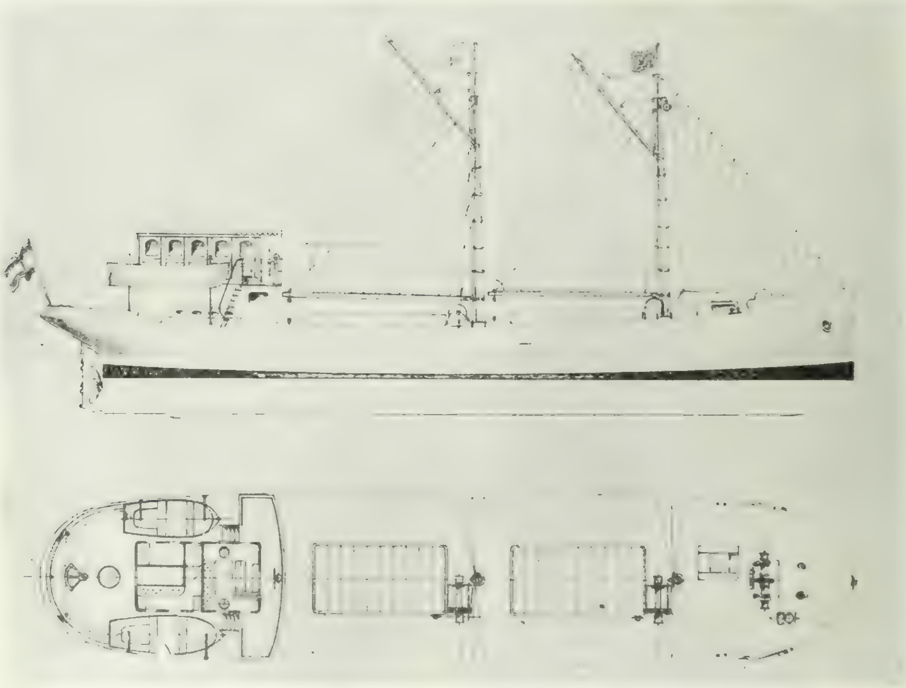
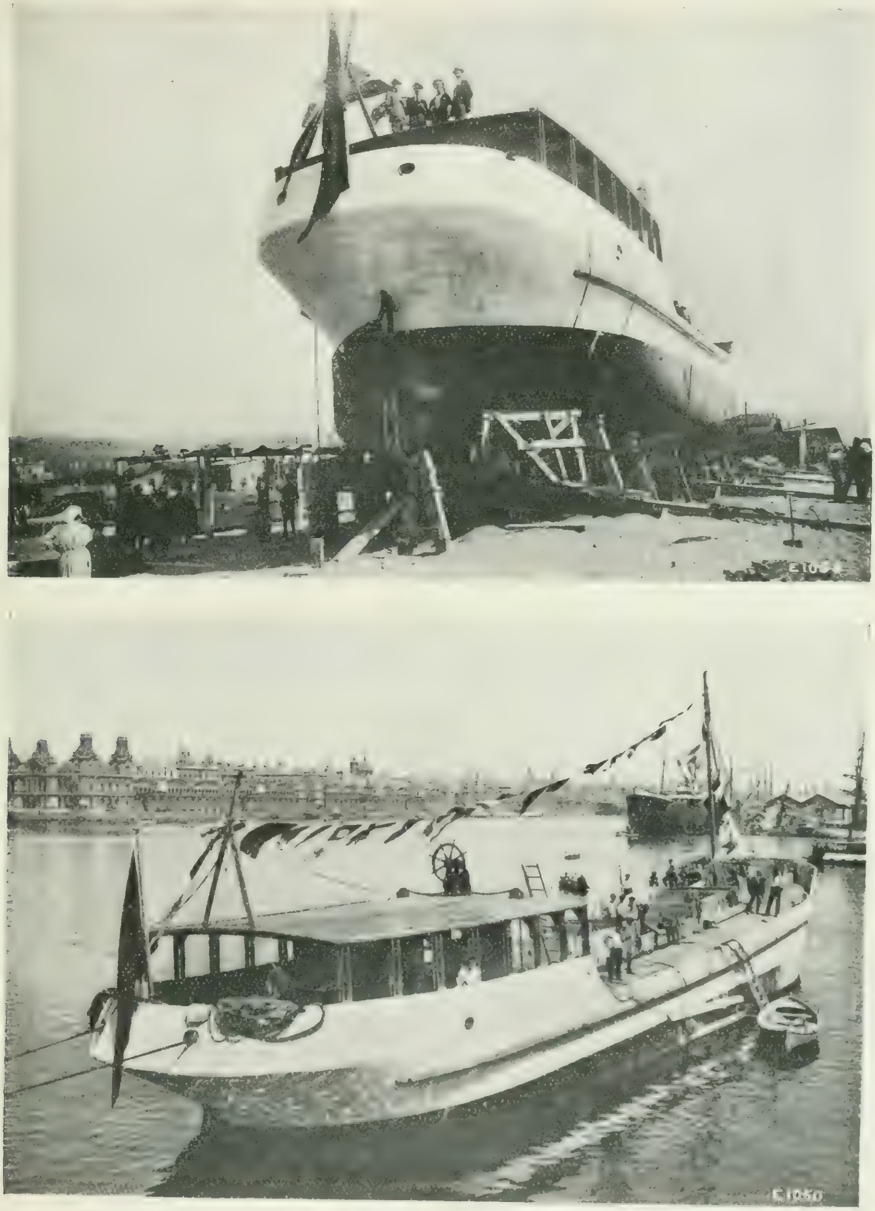


Fig. 45. Details of Design of a Spanish Concrete Boat.

In *Canada* a reinforced concrete single-screw steamer, 125 ft. by 22 ft. by 13 ft. built by the Atlas Construction Co., Ltd., was launched at Montreal in November, 1917, for service on the Great Lakes.



Figs. 46 & 47. View of Spanish Reinforced Concrete Vessel before and after launching.

In *Italy*, since the outbreak of war, more than 300 concrete boats and pontoons have been in use both for inland and coastal traffic. Most of the barges have been built by C. Gabellini, of Rome, and are of the type shown in *Figs*, 41, 42 and 43.

In *Denmark* a considerable amount of success has attended the construction of large caissons of reinforced concrete which have been floated to their destination and then submerged. The feasibility of caissons 32 ft. by 8 ft. by 25 ft. high has been long established by actual experience, but in the harbour basin at Copenhagen, built in 1917, caissons 162 ft. by 16 ft. by 32 ft. high were satisfactorily constructed, floated to their destination, and then submerged. *Fig.* 44 shows one of these caissons being towed to position.

The construction of one 100-ton concrete lighter in Denmark in 1917 has also been reported.

In *Switzerland* a floating dock on concrete pontoons was built in 1914 for the Zurich Yacht Club, and was reported, in *Engineering News Record*, November, 1917, as having been in satisfactory service ever since its construction.

In *Spain* the Sociedad Anon. Construcciones y Pavimentos, of Barcelona, built a concrete sailing barge of 450 tons capacity in 1917 for the transport of merchandise between France and Spain. This vessel (*Figs.* 45 to 47) is 113 ft. long, 24 ft. wide and 11½ ft. deep, with a displacement of 450 tons. Much larger vessels—including one of 1,500 tons capacity—are in course of construction by the same firm.

In *China* a 2,500 ton concrete ship has been launched at Tientsin, and a 2,200 ton concrete ship at Saigon, French Indo-China.

For use in *Africa* waters, two firms in this country are setting themselves out to supply barges and other craft constructed of concrete. The climatic conditions on the East Coast are not favourable for either wood or steel lighters, the former being subject to the Toreda worm, and the steel falls a victim to excessive corrosion.

In the *Dutch East Indies* one firm makes a speciality of concrete canoes and of lighters of 90 tons to 180 tons dead-weight capacity, motor boats up to 60 ft. in length, and various pontoons for carrying steam cranes and other heavy machinery.

The examples of concrete vessels in this chapter show quite clearly what has already been accomplished by the substitution of reinforced concrete for wood and steel in the construction of vessels of various types, and in various parts of the world. Many of the vessels mentioned are admittedly "trials," and were purposely made on conservative lines, with a limited amount of co-operation between experts in concrete construction and in shipbuilding. It is for present and future builders to make improvements on these vessels, paying due respect to their history and to the courage and far-sightedness of those who have invested so much capital, ingenuity, and hard work in the application of concrete to an industry in which its properties were largely unknown.

NOTES ON CONCRETE SHIPBUILDING.

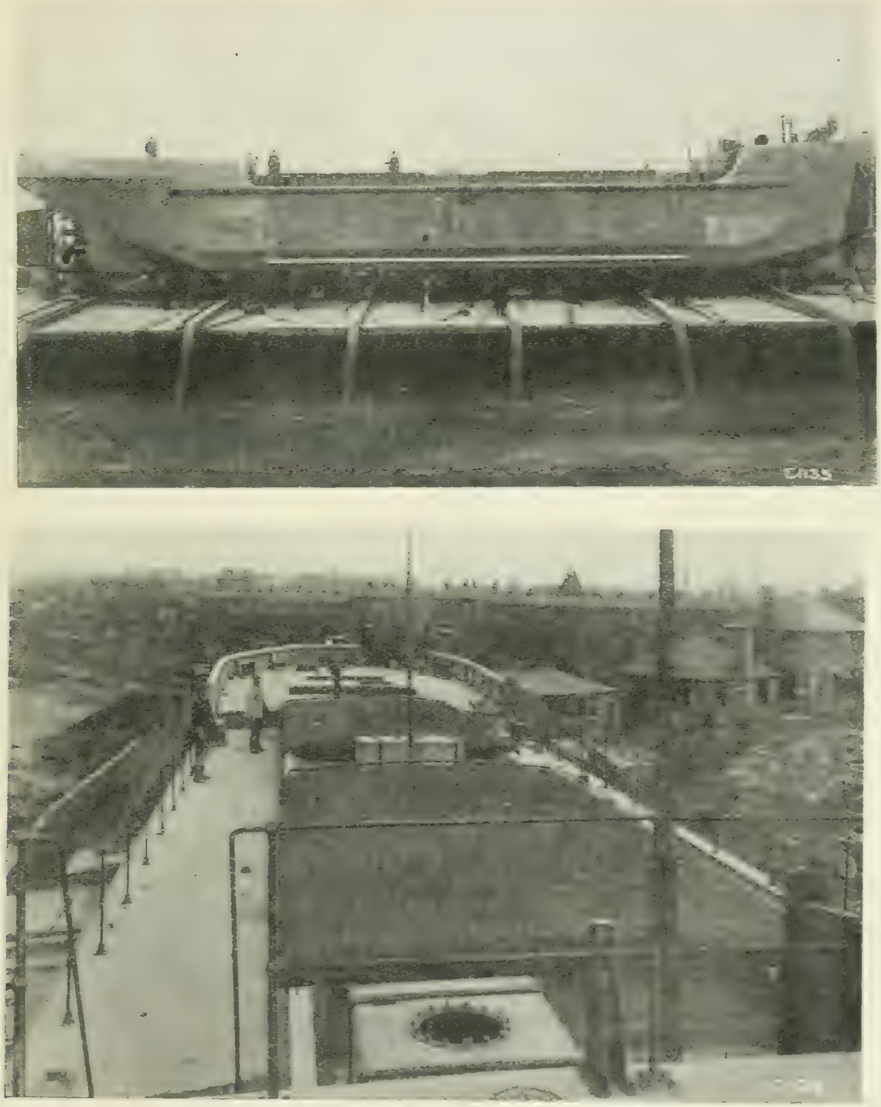
A REINFORCED CONCRETE VESSEL LAUNCHED AT FAVERSHAM.

On November 19th the first powered reinforced concrete vessel that has been built in the British Isles was launched at Faversham.

It is many years since a seagoing vessel was launched into Faversham Creek, and it is probable that there has never been one so large and so heavy as the *Molliette*. launched last month at Messrs. James Pollock Sons & Co., Ltd.'s, new shipyard at Upper Brents.

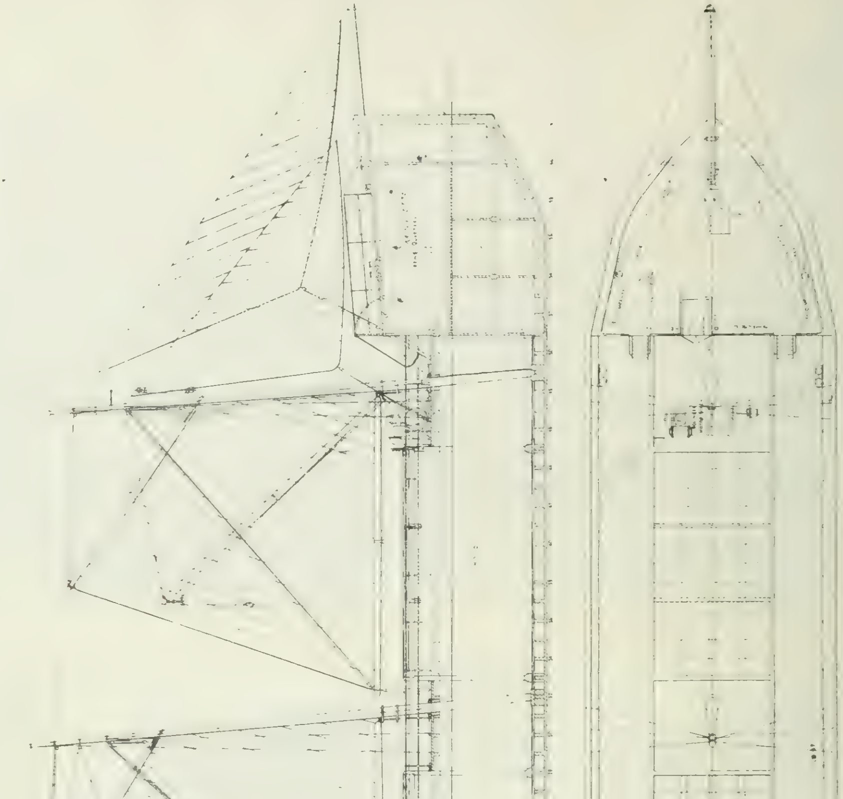
The *Molliette*, we are informed, is the first straight-lined seagoing vessel to be designed and approved by the authorities.

The dimensions are: Length over all, 131 ft.; breadth moulded, 25 ft.; depth moulded, 11 ft. 9 in.; draft loaded, 9 ft. 9 in. The vessel is designed to carry 320 tons of cargo. She is fitted as a three-masted fore and aft schooner. The main propelling machinery consists of the latest type Bolinder Crude Oil Engine of 120 brake-horse-power, sufficient to give the vessel a speed of 7 knots in calm weather, without the use of the sails. This engine does away entirely with water drip, and when under way has a silent and invisible exhaust, and should therefore be of interest to many in this locality.



The Reinforced Concrete Schooner *Molliette.*

The vessel is fitted with a raised quarter-deck and sunk forecastle, and has accommodation for captain and officers in a deck house on the former, whilst the crew is berthed in the latter. She is classed to Lloyd's " A " experimental, and is built on the monolithic system. The reinforcing consists of round rods, no " sections " of steel or iron being used. She has three transverse bulkheads, one at each end of



Plan and Section of the *Molliette.*

the hold, and one at the after end of the motor-room. The framing is on the transverse system, with three keelsons all fore and aft. The hatch coamings are continuous from the raised quarter front of the after end of the forecastle, and the decks are supported by a few reinforced concrete pillars at the sides of the hatches. The outer skin is protected at the decks by a wood rubbing strake. It will, as a matter of interest, be observed that owing to the narrowness of the creek the vessel had to be launched broadside on.

AN IMPROVED METHOD OF CONCRETE SHIP CONSTRUCTION.

When constructing concrete vessels in the customary manner, the bottom of the hull cannot be concreted until the reinforcement for the bottom and side walls, the bulkheads, the transverse frames and the keelsons, have been assembled and shuttered. This method of procedure causes a good deal of inconvenience and loss of time, especially as wood shavings and chips and *débris* generally are apt to collect in the series of compartments formed by the moulds for the frames and keelsons. With the object of simplifying construction, an improved method has been patented by Messrs. Mouchel & Partners, Ltd., permitting the bottom of the vessel to be concreted before the assembly of the reinforcement for the remainder of the hull, and also providing for the longitudinal bracing of the frames without the ordinary keelsons, the connection of which with the frames involves an undesirable amount of somewhat complicated work in the way of moulds and otherwise. Special provision is made for the interlocking and anchorage of the reinforcing bars in the bottom and adjoining parts, and so far as the continuity and monolithic character of the finished hull are concerned, there will be no difference between vessels' construction on the old and new systems. The value of the new method lies in the simplification of work, the facilities given for the more efficient execution of concreting work, and the important saving of time and money that will be effected. This may be taken as one of the many improvements which will undoubtedly be introduced from time to time in concrete ship construction.

ELECTRICAL WELDING IN CONCRETE SHIPS.

Electrical welding has recently been introduced in British concrete shipyards with satisfactory results for connecting various members of the reinforcement as an alternative to the use of wire ties. The welds are very quickly made and hold the bars so firmly in their final positions that the blocks, wedges, and distance pieces otherwise necessary can be entirely eliminated. Oxy-acetylene welding is also under consideration for the same purpose.

AN AMERICAN CONCRETE VESSEL.

In W. E. McNeillies American patent (No. 984,285), the vessel is reinforced by angle irons (13) passing around its sides with their lower ends bolted to the keel, the latter being built of a vertical placed bar, 10, supported on each side by an angle iron 11, secured by screws, 12, A stout wire mesh is attached to the outside of the angle irons, and is covered both internally and externally with concrete.

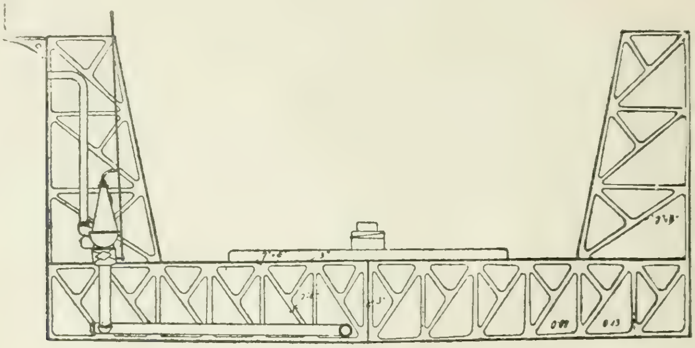
THE LARGEST SHIPYARD IN EUROPE.

According to *Il Cemento*, what will probably be the largest shipyard in Europe will shortly be constructed on the shore of Carrara, a company having just been registered by a group of capitalists. It will contain 15 docks for building large vessels as well as similar facilities for building a large number of small ones. The proposed yard will occupy all the coast between Parmignola and Via Bassa Granda, including Via Lazzoni, and will have a frontage of 3,330 ft., which will be extended to 4,300 ft. later, and a depth of 1,700 ft., except for a small part, where it will only be 1,000 ft, A special harbour basin 5,000 ft. across, and with a water surface of 3,000 ft. by 1,300 ft. will be built of concrete caissons for the service of the shipyard, and for launching the vessels. Special ways will be provided for fitting up vessels, and the yard will have its own railway connections with the Marmifera Railway. It will be fitted throughout with the most modern appliances, and with every convenience for the comfort and well being of its employees.

NEW CONCRETE VESSELS IN ITALY.

The firm of Ditta, of Livorno (Italy), has recently constructed 250-ton barges, caissons, and floating docks of reinforced concrete in the ports of Spezzia, Salerno

Tripoli, and Venice. These are built in sections previously prepared and joined together as required. At Venice, 25 caissons, 170 ft. long, 17 ft. wide, and 35 ft. high were constructed in the Spezzia shipyard, and the firm have built two lighters, each 333 ft. long, 33 ft. wide, and 23 ft. high, which satisfactorily underwent loading tests of about 200 tons.



SECTION OF A FLOATING DOCK FOR TORPEDO BOATS.

The accompanying illustration shows a section of a floating dock, 230 ft. long, for torpedo boats.—*Il Cemento.*

A GERMAN CONCRETE SHIPBUILDING FIRM.

A small shipbuilding firm in Hamburg has been taken over and converted into the first large concrete shipbuilding firm in Germany. The new concern will build concrete ships, floating docks and other water-borne structures, orders for these being now in hand. A new and much larger yard near Finkenwaeder will be used. The authorised capital is £50,000. The business will be managed by Wayss and Freytag, A.G., at Neustadt a. H. in association with a strong directorate.—*Beton u. Eisen.*

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